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DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 223

[Docket No. 220830-0177]

RTID 0648-XR071

Endangered and Threatened Wildlife and Plants: Proposed Rule to List the Queen Conch as Threatened Under the Endangered Species Act (ESA)

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Proposed rule; request for comments.

SUMMARY: We, NMFS, announce a proposed rule to list the queen conch (*Aliger gigas,* previously known as *Strombus gigas*) as a threatened species under the Endangered Species Act (ESA). We have completed a comprehensive status review for the queen conch. After considering the status review report, and after taking into account efforts being made to protect the species, we have determined that the queen conch is likely to become an endangered species within the foreseeable future throughout its range. Therefore, we propose to list the queen conch as a threatened species under the ESA. Any protective regulations determined to be necessary and advisable for the conservation of the queen conch under ESA would be proposed in a subsequent **Federal Register** announcement. We solicit information to assist this listing determination, the development of proposed protective regulations, and designation of critical habitat within U.S jurisdiction.

DATES: Information and comments on this proposed rule must be received by [*insert date 60 days after date of publication in the* ***FEDERAL REGISTER***]. Public hearing requests must be requested by [*insert date 45 days after publication in the* ***FEDERAL REGISTER***].

ADDRESSES: You may submit comments, information, or data on this document, identified by the code NOAA-NMFS-2019-0141 by any of the following methods:

- *Electronic Submissions:* Submit all electronic comments via the Federal eRulemaking Portal. Go to *www.regulations.gov* and enter NOAA-NMFS-2019-0141 in the Search box. Click on the "Comment" icon, complete the required fields, and enter or attach your comments.
- *Mail*: NMFS, Southeast Regional Office, 263 13th Avenue South, St. Petersburg, FL 33701;
- *Instructions:* Comments sent by any other method, to any other address or individual, or received after the end of the comment period, might not be considered by NMFS. All comments received are a part of the public record and will generally be posted for public viewing on www.regulations.gov without change. All personal identifying information (*e.g.,* name, address, *etc.*), confidential business information, or otherwise sensitive information submitted voluntarily by the sender will be publicly accessible. NMFS will accept anonymous comments (enter ''N/A'' in the required fields if you wish to remain anonymous). You can find the petition, status review report, **Federal Register** notices, and the list of references electronically on our Web site at *https://www.fisheries.noaa.gov/species/queen-conch*

FOR FURTHER INFORMATION CONTACT: Calusa Horn, NMFS Southeast Regional Office, 727-551-5782 or *Calusa.Horn@noaa.gov,* or Maggie Miller, NMFS Office of Protected Resources, 301-427-8457 or *Margaret.H.Miller@noaa.gov.*

SUPPLEMENTARY INFORMATION:

Background

On February 27, 2012, we received a petition from WildEarth Guardians to list the queen conch as threatened or endangered throughout all or a significant portion of its range under the ESA. We determined that the petitioned action may be warranted and published a positive 90-day finding in the **Federal Register** (77 FR 51763; August 27, 2012). After conducting a status review, we determined that listing queen conch as threatened or endangered under the ESA was not warranted and published our determination in the **Federal Register** (79 FR 65628; November 5, 2014). In making that determination, we first concluded that the queen conch was not presently in danger of extinction, nor was it likely to become so in the foreseeable future. We also evaluated whether there was a portion of the queen conch's range that was "significant," applying the definition of that term from the joint U.S. Fish and Wildlife Service/NMFS Policy on Interpretation of the Phrase "Significant Portion of Its Range" (SPR Policy; 79 FR 37580, July 1, 2014). We concluded that available information did not indicate any "portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range."

WildEarth Guardians and Friends of Animals filed suit on July 27, 2016, in the U.S. District Court for the District of Columbia, challenging our decision not to list queen conch as threatened or endangered under the ESA. On August 26, 2019, the court vacated our determination that listing queen conch under the ESA was not warranted and remanded the determination back to the NMFS based on our reliance on the SPR Policy's particular threshold for defining "significant," which was vacated nationwide in 2018 (though other aspects of the policy remain in effect). See *Desert Survivors* v. *U.S. Dep't of Interior*, 321 F. Supp. 3d 1011 (N.D. Cal. 2018). Following the 2019 ruling of the U.S.

District Court for the District of Columbia, we announced the initiation of a new status review of queen conch and requested scientific and commercial information from the public (84 FR 66885, December 6, 2019). We received 12 public comments in response to this request. We also provided notice and requested information from jurisdictions through the Western Central Atlantic Fishery Commission (WECAFC), Caribbean Regional Fisheries Mechanism (CRFM), and the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) Authorities. All relevant, new information was incorporated as appropriate in the status review report and in this proposed rule. In particular, new information considered in the status review report includes: 1) fisheries landings data (1950-2018) from the Food and Agriculture Organization (FAO); 2) reconstructed landing histories (1950-2016) from the Sea Around Us (SAU) project; 3) results from recent genetic studies; and 4) the results from regional hydrodynamics and population connectivity modeling.

Listing Determinations under the ESA

We are responsible for determining whether species are threatened or endangered under the ESA (16 U.S.C. 1531 *et seq*.). To make this determination, we first consider whether a group of organisms constitutes a "species" under section 3 of the ESA, then whether the status of the species qualifies it for listing as either threatened or endangered. Section 3 of the ESA defines species to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Because the queen conch is an invertebrate, we do not have the authority to list individual populations as distinct population segments.

Section 3 of the ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range" and a threatened species as one "which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Thus, in the context of the

ESA, the Services interpret an "endangered species" to be one that is presently at risk of extinction. A "threatened species," on the other hand, is not currently at risk of extinction, but is likely to become so in the foreseeable future. In other words, a key statutory difference between a threatened and endangered species is the timing of when a species may be in danger of extinction, either now (endangered) or in the foreseeable future (threatened). Additionally, as the definition of "endangered species" and "threatened species" makes clear, the determination of extinction risk can be based on either the range-wide status of the species, or the status of the species in a "significant portion of its range." A species may be endangered or threatened throughout all of its range or a species may be endangered or threatened within a significant portion of its range (SPR).

Section 4(a)(1) of the ESA requires us to determine whether any species is endangered or threatened as a result of any of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence (section 4(a)(1)(A)–(E)). Section 4(b)(1)(A) of the ESA requires us to make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account conservation efforts being made by any State or foreign nation or political subdivision thereof to protect the species.

Status Review

We convened a team of seven agency scientists to conduct a new status review for the queen conch and prepare a report. The status review team (SRT) was comprised of natural resource management specialists and fishery biologists from the NMFS Southeast Regional Office, West Coast Regional Office, Office of Protected Resources, and Southeast Fisheries Science Center (SEFSC). The SRT had group expertise in queen conch life history and ecology, population dynamics, connectivity modeling, fisheries management and stock assessment science, and protected species management and conservation. The status review report presents the SRT's professional judgment of the extinction risk facing the queen conch but makes no recommendation as to the listing status of the species. The status review report was subjected to independent peer review as required by the Office of Management and Budget Final Information Quality Bulletin for Peer Review (M–05–03; December 16, 2004). The status review report was peer reviewed by three independent specialists selected from the scientific community, with expertise in queen conch biology and ecology, conservation and management, and specific knowledge of threats to queen conch. The peer reviewers were asked to evaluate the adequacy, appropriateness, and application of data used in the status review as well as the findings resulting from that data. All peer reviewer comments were addressed prior to finalizing the status review report.

We subsequently reviewed the status review report, its cited references, and public and peer reviewer comments. We determined the status review report, upon which this proposed rule is based, provides the best available scientific and commercial information on the queen conch. Much of the information discussed below on queen conch biology and ecology, distribution and connectivity, density and abundance, threats, and extinction risk is taken from the status review report. However, we have independently applied the statutory provisions of the ESA, including evaluation of the factors set forth in section 4(a)(1)(A)–(E), our regulations regarding listing determinations, conservation efforts, and the aspects of our SPR Policy that remain valid in making our determination that the queen conch meets the definition of a threatened species under the ESA.

Life History, Ecology, and Status of the Petitioned Species

Taxonomy and Species Description

Aliger gigas, originally known as *Strombus gigas* or more recently as *Lobatus gigas*, is commonly known as the queen conch. The queen conch belongs to the family Strombidae and the most recent classification places the queen conch under the genus *Aliger* (Maxwell *et al.* 2020) in the class Gastropoda, order Neotaenioglossa, and family Strombidae. Other accepted synonyms include: *Strombus gigas* (Linnaeus, 1758); *Lobatus gigas* (Linnaeus, 1758); *Strombus lucifer* (Linnaeus, 1758); *Eustrombus gigas* (Linnaeus, 1758); *Pyramea lucifer* (Linnaeus, 1758); *Strombus samba* (Clench 1937); *Strombus. horridus* (Smith 1940); *Strombus verrilli* (McGinty 1946); *Strombus canaliculatus* (Burry 1949); and *Strombus pahayokee* (Petuch 1994), as cited in (Landau *et al.* 2009).

The queen conch is a large marine gastropod mollusk. Adult queen conch have a heavy shell (5 pounds, 2.3 kilograms (kg)) with spines on each whorl of the spire and flared aperture. The shell grows as the mollusk grows, forming into a spiral shape with a glossy pink interior. The outside of the shell becomes covered by an organic periostracum ("around the shell") layer as the queen conch matures that can be much darker than the natural color of the shell. Characteristics used to distinguish queen conch from other family members include: (1) large, heavy shell; (2) short, sharp spires; (3) brown and horny operculum; and (4) pink interior of the shell (Prada *et al.* 2009).

Distribution, Movements, and Habitat Use

The queen conch is distributed throughout the Caribbean Sea, the Gulf of Mexico, and around Bermuda. Its range includes the following countries, territories, and areas: Anguilla, Antigua and Barbuda, Aruba, Barbados, The Bahamas, Belize, Bermuda, Bonaire, British Virgin Islands, Brazil, Cayman Islands, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Grenada, Guadeloupe and Martinique, Guatemala, Haiti, Honduras, Jamaica, Mexico, Montserrat, Nicaragua, Panama, Puerto Rico, Saba, St. Barthelemy, St. Martin, St. Eustatius, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos, U.S. Virgin Islands, the United States (Florida), and Venezuela (Theile 2001; see File S1 in Horn *et al.* 2022).

As conch develop they use different habitat types including seagrass beds, sand flats, algal beds, and rubble areas from a few centimeters deep to approximately 30 meters (m) (Brownell and Stevely 1981). After the eggs of queen conch hatch, the veligers (larvae) drift in the water column for up to 30 days depending on phytoplankton concentration, temperature, and the proximity of settlement habitat. The minimum pelagic duration is reported from four field studies to be 16 days (Brownell 1977; Davis 1994, 1996; Salley 1986), but can range from 21 days to 30 days (Brownell 1977; D'Asaro 1965; Davis 1994; Paris *et al.* 2008; Salley 1986) with a mean of approximately 25 days. These veligers are found primarily in the upper few meters of the water column (Paris *et al.* 2008; Posada and Appeldoorn 1994; Stoner 2003; Stoner and Davis 1997) where they feed on phytoplankton. When the veligers are morphologically and physiologically ready, they metamorphose into benthic animals in response to trophic cues from their seagrass habitat (Davis 2005). The key trophic cues shown to induce metamorphosis are epiphytes associated with macroalgae and sediment (Davis and Stoner 1994). Settlement locations are usually areas that have sufficient tidal circulation and high macroalgae production. Upon metamorphosis, veligers settle to the bottom and bury completely into the sediment where they spend much of their first year of life. They emerge about a year later as juveniles measuring around 60 millimeters (mm) shell length (Stoner 1989b). When juvenile conch first emerge from the sediment and move to nearby seagrass beds, densities can be as high as 200-2000 conch/hectare (Stoner 1989a; Stoner and Lally 1994; Stoner 2003). A hectare (ha) is an area 100 meters by 100 meters, equivalent to 2.471 acres.

Queen conch nursery areas primarily occur in back reef areas (*i.e.,* shallow sheltered areas, lagoons, behind emergent reefs or cays) of medium seagrass density, at depths between 2 to 4 m, with strong tidal currents of at least 50 centimeters (cm)/second (Stoner 1989a), and frequent tidal water exchanges (Stoner *et al.* 1996; Stoner and Waite 1991). Seagrass is thought to provide both nutrition and protection from predators (Ray and Stoner 1995; Stoner and Davis 2010). The structure of the seagrass beds decreases the risk of predation (Ray and Stoner 1995), which is very high for juveniles (Appeldoorn 1988c; Stoner and Glazer 1998; Stoner *et al.* 2019). Posada *et al.* (1997) observed that the most productive nurseries for queen conch tend to occur in shallow (< 5-6 m deep) seagrass meadows. Jones and Stoner (1997) found that optimal nursery habitat occurred in areas of medium density seagrass, particularly areas associated with strong ocean currents or hydrographic conditions. Boman *et al.* (2019) observed a significantly higher probability of positive growth in juvenile conch in native seagrass compared to invasive seagrass. In The Bahamas, juveniles were found only in areas within 5 km from the Exuma Sound inlet, emphasizing the importance of currents and frequent tidal water exchange that affects both larval supply and growth of their algal food (Jones and Stoner, 1997). However, there are certain exceptions, such as in Florida, where many juveniles are found on shallow algal flats, or in Jamaica, where they can be found on deep banks such as Pedro Bank.

While the early life stages of queen conch primarily occur in shallow waters with dense seagrass meadows, adult queen conch can be found in a wider range of environments (Stoner *et al.* 1994), including sand, algal flats, or coral rubble (Acosta 2001; Stoner and Davis 2010). Queen conch are rarely, if ever, found on soft bottoms composed of silt or mud, or in areas with high coral cover (Acosta 2006). The movements of adult queen conch are associated with factors like changes in temperature, food availability, and predation. Adult conch are typically found in shallow, clear water of oceanic or near-oceanic salinities at depths generally less than 75 m, but are most common in waters less than 30 m (McCarthy 2007). Depth limitation is based mostly on light attenuation limiting their photosynthetic food source (*e.g.,* filamentous alga) (McCarthy 2007; Creswell, 1994; Ray and Stoner 1994; Randall 1964). The average home range size for an individual queen conch is variable and has been measured at 5.98 ha in Florida (Glazer *et al.* 2003), 0.6 to 1.2 ha in Barbados (Phillips *et al.* 2010), and 0.15 to 0.5 ha in the Turks and Caicos Islands (Hesse 1979). Studies have suggested that adult conch move to different habitat types during their reproductive season, but afterwards return to feeding grounds (Glazer *et al.* 2003; Stoner and Sandt 1992; Hesse 1979). In general, adult conch do not move very far from their feeding grounds during their reproductive season (Stoner and Sandt 1992).

Diet and Feeding

Queen conch are herbivores and primarily feed on macroalgae and seagrass detritus (Ray and Stoner 1995; Creswell 1994). The production of red and green algae, which can be highly variable, has been shown to directly affect the growth of juvenile conch (Stoner 2003; Stoner *et al.* 1995; Stoner *et al.* 1994). Organic material in the sediment (benthic diatoms and particulate organic matter and cyanobacteria) has also been suggested to be a source of nutrition to juvenile conch (Boman *et al.* 2019; Serviere-Zaragoza *et al.* 2009; Stoner *et al.* 1995; Stoner and Waite 1991). Stoner and Waite (1991) also showed that macroalgae were the most likely food source of juvenile conch (shell length 120−140 mm) in native seagrass beds in The Bahamas. Several studies have indicated that seagrass detritus is an important secondary food source for juvenile queen conch, in particular detritus of *T. testudinum* (Stoner and Waite 1991; Stoner 1989a). In sand habitats, juveniles can also feed on diatoms and cyanobacteria that are found in the benthos (Creswell 1994; Ray and Stoner 1995).

Age and Growth

Queen conch are estimated to have a life span of 25-30 years (Davis 2005; McCarthy 2007). As with many gastropods, growth in queen conch is determinate and strongly influenced by the environment (Martín-Mora *et al.* 1995; Alcolado, 1976). The species has determinate growth and reaches maximum shell length before sexual maturation; thereafter the shell grows only in thickness (Stoner *et al.* 2012; Appeldoorn 1988a). Conch are often considered to be mature when the lip is flared, however Appeldoorn (1988c) observed that the verge (the male reproductive organ) of thin-lipped males in Puerto Rico was not yet functional, and true reproductive maturity did not occur until at least two months after the lip flared outward at about 3.6 years of age. The result is that thin-lipped individuals probably do not mate or spawn in the first reproductive season after the shell lip flares, and are at least 4 years old before first mating. Once the shell lip is formed, the shell does not increase in length (Appeldoorn 1996; Tewfik *et al.* 1998). Because the shell lip continues to thicken upon the onset of maturity (Appeldoorn 1988a), studies have found that shell lip thickness is a better indicator of sexual maturity rather than the formation of the flared lip (Appeldoorn 1994b; Clerveaux *et al.* 2005; Stoner *et al.* 2012c). With the onset of sexual maturity, tissue growth decreases and switches from primarily thickening of the meat to increasing the weight of the gonads. Once the conch is around ten years of age, the shell volume starts to decrease, as layers of the shell mantle are laid down from the inside (Randall 1964). Eventually, the room inside the shell can no longer accommodate the tissue and the conch will start to decrease its tissue weight (CFMC and CFRAMP 1999). Stoner *et al.* (2012c) found that after shell lip thickness reached 22 to 25 mm, both soft tissue and gonad weight decreased.

Reproductive Biology

Queen conch reproduce via internal fertilization. Males and females are distinguished by either a verge (the male reproductive organ) or egg groove.

Approximately three weeks after copulation the female lays a demersal egg mass on coarse sand of low organic content, completing deposition within 24-36 hours (D'Asaro 1965; Randall 1964). The egg mass consists of a long, continuous, egg-filled tube that folds and sticks together in a compact crescent shape, adhering to sand grains that provide camouflage and discourage predation. After an incubation period of approximately five days, the larvae emerge and assume a pelagic lifestyle (Weil and Laughlin 1984; D'Asaro 1965).

Assessments of fecundity require knowledge of the population sex ratio, spawning season duration, rate of spawning during the season, number of eggs per egg mass, and the relationship between body mass and age (Appeldoorn 1988c). Few studies have investigated these factors concurrently, and the variability reported in these metrics is high. For example, estimates of the number of eggs contained within each egg mass range from 150,000 to 1,649,000 (Appeldoorn 2020; Delgado and Glazer 2020; Appeldoorn 1993; Berg Jr. and Olsen 1989; Mianmanus 1988; Weil and Laughlin 1984; D'Asaro 1965; Randall 1964; Robertson 1959). Additionally, females are capable of storing eggs for several weeks before laying an egg mass, which means it is possible that multiple males have fertilized the same eggs (Medley 2008). The ability to store sperm is advantageous for conch populations since females are still capable of laying egg masses without encountering another male. The number of egg masses produced per female is also highly variable and ranges between 1 and 25 per female per season for experiments performed in different areas throughout the queen conch range (Appeldoorn 1993; Berg Jr. and Olsen 1989; Davis *et al.* 1984; Weil and Laughlin 1984; Davis and Hesse 1983).

The number of masses produced as well as the number of eggs per mass may decrease toward the end of the reproductive season (Weil and Laughlin 1984), but individual variability may also be influenced by spawning frequency and the size and number of egg masses produced during the season (Appeldoorn 2020). Differences in spawning rates have been attributed to spawning site selection, population densities, and food selection and availability, among other variables. Variability in spawning activity may also be correlated to water temperature and weather conditions. For example, reproductive activity decreased with increasing water turbulence (Davis *et al.* 1984) and reproduction peaked with longer days, warmer water temperatures, and relatively stable circulation patterns (Stoner *et al.* 1992).

Seasonal movements, usually associated with the initiation of the reproductive season, are widely known for queen conch. Weil and Laughlin (1984) reported that adult conch at Los Roques, Venezuela, moved from offshore feeding areas in the winter to summer spawning grounds in shallow, inshore sand habitats. In the Turks and Caicos, adult conch moved from seagrass to sand-algal flats with the onset of winter (Hesse 1979). Movements to shallower habitats have also been reported for deep-water populations at St. Croix, U.S. Virgin Islands (Coulston *et al.* 1987). Increasing water temperature and photoperiod are thought to trigger large-scale migrations and the subsequent initiation of mating. In locations where adult conch are abundant, these migrations culminate in the formation of reproductive aggregations. These aggregations generally form in the same locations each year (Marshak *et al.* 2006; Glazer and Kidney 2004; Posada *et al.* 1997) and are dominated by older individuals that produce viable egg masses (Berg Jr. *et al.* 1992). However, in some areas large-scale movements do not occur. For example, in the United States (Florida Keys), adult aggregations are relatively persistent throughout the year, although reproductive activity does not occur year-round (Glazer and Kidney 2004; Glazer *et al.* 2003). Queen conch found in the deep waters near Puerto Rico are geographically isolated from nearshore, shallow habitats and remain offshore during the spawning season (García-Sais *et al.* 2012). The distribution of feeding and spawning habitats may also be an important factor in the timing and extent of adult movements.

Multiple studies involving visual surveys of mating and spawning events and histological examinations of gonadic activity show that the duration and intensity of the spawning season varies extensively throughout the queen conch's range (Table 1 in Horn *et al.* 2022). External variables such as temperature, photoperiod, and weather events interact to mediate seasonality in reproductive and spawning behaviors. Generally, reproductive activity begins earlier and extends later into the year with decreasing latitude. Visual surveys of reproductive activity have reported the reproductive season to extend from May to September in Florida (D'Asaro 1965), May to November in Puerto Rico (Appeldoorn 1985), March to September in the Turks and Caicos (Davis *et al.* 1984; Hesse 1976), and February through November in the U.S. Virgin Islands (Coulston *et al.* 1987; Randall 1964). In warmer regions such as Cuba and Mexico's Banco Chinchorro, reproductive activity can occur throughout the year (Cala *et al.* 2013; Corral and Ogawa 1987; Cruz S. 1986); however, there is a seasonal peak in activity in most areas during the warmest months, usually from July to September (Aldana-Aranda *et al.* 2014).

Spawning Density

Depensatory mechanisms have been implicated as a major factor limiting the recovery of depleted queen conch populations (Stoner *et al.* 2012c; Appeldoorn 1995). Depensation occurs when a population's decreased abundance or density leads to a reduced per capita growth rate, thereby reducing the population's ability to recover. Reproductive potential is primarily reduced by the removal of mature adults from the population (Appeldoorn 1995). Empirical observations have suggested mating and egg-laying in queen conch are directly related to the density of mature adults (Stoner *et al.* 2012c; Stoner *et al.* 2011; Stoner and Ray-Culp 2000). In animals that aggregate to reproduce, low population densities can make it difficult or impossible to find a mate (Stoner and Ray-Culp 2000; Erisman *et al.* 2017; Rossetto *et al.* 2015; Stephens *et al.* 1999; Appeldoorn 1995). Challenges associated with mate finding are likely exacerbated for slow-moving animals such as the queen conch (Doerr and Hill 2013; Glazer *et al.* 2003). This limitation directly impacts the species' ability to increase its population size because increased "search time" depletes energy resources, reducing the rate of gametogenesis and the overall reproductive potential of the population. Simulations by Farmer and Doerr (in review) confirm that limitations on mate finding associated with density are the primary driver behind observed patterns in queen conch mating and spawning activity, but similar to field observations by Gascoigne and Lipcius (2004), it is unlikely to be the only explanation for lack of reproductive activity at low densities.

An additional postulated depensatory mechanism is the breakdown of a positive feedback loop between contact with males and the rate of gametogenesis and spawning in females, where copulation stimulates oocyte development and maturation, leading to more frequent spawning (Appeldoorn 1995). Copulation in conch is more likely in spawning than non-spawning females, providing an additional positive feedback mechanism that amplifies the effect at high densities (Appeldoorn 1988a). Evidence supporting this idea has been provided by several studies that reported a consistent lag at the start of the reproductive season between first observations of copulation and first spawning (Weil and Laughlin 1984; Brownell 1977; Hesse 1976; Randall 1964). This lag period, averaging three weeks, may represent the time required to achieve oocyte maturation after first copulation. Farmer and Doerr (in review) considered differences in adult density, movement speeds, scent-tracking, barriers to movement, interbreeding rest periods, perception distance, and sexual facilitation. Sexual facilitation was the only mechanism explaining the lack of empirical observations of mating at relatively low population densities, providing statistical confirmation that the reductions of densities caused by overfishing of spawning aggregations increases the probability of recruitment failure beyond what would be anticipated from delays in mate finding alone. This is consistent with observations by Gascoigne and Lipcius (2004), which indicate that in addition to depensatory mechanisms associated with mate finding, delayed functional maturity at low density sites can explain declines in reproductive activity.

Because direct physical contact is necessary for copulation and queen conch are slow moving, the density of mature adults within localized queen conch populations is a critical and complex factor governing mating success and population sustainability. Although many surveys of conch populations have been completed over the last half century, few studies have simultaneously investigated the relationship between adult density and reproductive rates. Of these, the reported rates of reproductive activity associated with surveys of adult populations have varied extensively across multiple jurisdiction as density is dependent on the scale of measurement and the targeted area surveyed. For example, in The Bahamas where queen conch populations are at densities near 200 adults per hectare, Stoner and Ray-Culp (2000) reported mating and spawning rates of approximately 13 percent and 10 percent, respectively. During continued surveys in fished areas (Berry and Andros Islands) and a no-take reserve (Exuma Cays Land and Sea Park) of The Bahamas, Stoner *et al.* (2012c) observed that, at a mean adult density of 60 conch/ha within the Exuma Cays Land and Sea Park, 9.8 percent of adult queen conch were mating, while at 118 adult conch/ha at Andros Island, approximately 2.4 percent were mating, and at 131 adult conch/ha at the Berry Islands, only 5.9 percent were involved in mating activity. Doerr and Hill (2018) reported reproductive activity in 2.4 percent of adult conch located across the shelf of St. Croix, U.S. Virgin Islands, with the lowest mean density of adult queen conch at survey sites, where reproductive activity occurred, was 63.7 adult conch/ha. Of these studies, the highest densities were reported from Cuba, where at one protected site with densities of 223 adult conch/ha only 0.3 percent of adult queen conch were mating, while at another site with a reported adult density of 497 conch/ha, 3.7 percent of conch were mating, and 2.5 percent were involved in spawning (Cala *et al.* 2013). In Colombia, however, reproductive activity demonstrated by the presence of egg masses was reported in areas with population densities as low as 24 and 11 conch/ha (Gómez-Campo *et al.* 2010). The scale over which these observations were recorded and subsequent interpretation of the spatial dispersion of queen conch are critical to understanding differences among study conclusions.

As previously discussed, queen conch life history traits make them vulnerable to depensatory mechanisms. When reproductive fitness declines such that per capita population growth rate becomes negative, localized extinction may result (Courchamp *et al.* 1999; Allee 1931). Appeldoorn (1988a) initially suggested that queen conch may have a critical density for egg production, and Stoner and Ray-Culp (2000) provided evidence for demographic effects in queen conch populations, reporting a complete absence of mating and spawning in population densities less than 56 and 48 adult conch/ha, respectively. They concluded that the absence of reproduction in low-density populations was primarily related to encounter rate and noted that reproductive activity reached an asymptotic level near 200 adult conch/ha (Stoner and Ray-Culp 2000). Based on these studies, 50 adult conch/ha is generally accepted as the minimum threshold required to achieve some level of reproductive activity within a given conch population (Gascoigne and Lipcius 2004; Stoner and Ray-Culp 2000; Stephens and Sutherland 1999; Appeldoorn 1995). Conversely, Delgado and Glazer (2020) reported the highest adult queen conch threshold densities below which no reproduction was observed, with no mating occurring at aggregation densities below 204 adult conch/ha and no spawning at aggregation densities below 90 adult conch/ha. Given the highly aggregated nature of queen conch (Glazer and Kidney 2004; Glazer *et al.* 2003), managing for minimum cross-shelf densities (*i.e.,* 100 adult conch/ha) does not specifically protect the high-density spawning aggregations where most reproduction occurs. Thus, the Delgado and

Glazer (2020) contend that queen conch fishery managers should identify and protect high density queen conch spawning aggregations irrespective of cross-shelf densities.

The persistent formation of adult queen conch aggregations may help to sustain some populations as evidenced by long-term intra-aggregation surveys conducted by Delgado and Glazer (2020) in Florida, which show that, as aggregation densities increase both mating and spawning increase, correspondingly. Delgado and Glazer (2020) observed an increase in mating activity, peaking at 71 percent of the aggregation at densities greater than 800 adult conch/ha. In addition, a greater portion of the aggregations were found to have egg-laying females as aggregation density increased. The percentage of aggregations with spawning females reached a peak of just over 84 percent at aggregation densities greater than 600 adult conch/ha (Delgado and Glazer 2020). Similarly, Stoner *et al.* (2012b) reported that mating frequency increased at higher densities of adults in The Bahamas, with a maximum of 34 percent of the population mating at approximately 2,500 adult conch/ha. Repeat visual surveys in the same sites in The Bahamas have provided evidence of this susceptibility, revealing that adult densities in the Exuma Cays Land and Sea Park have declined significantly over 22 years due to lack of recruitment (Stoner *et al.* 2019). Stoner *et al.* (2019) further concluded that most conch populations in The Bahamas are currently at or below critical densities for successful mating and reproduction and that significant management measures are needed to preserve the stock. Similar long-term declines of reproductively active adult conch have been reported within the Port Honduras Marine Reserve in southern Belize. Densities of conch in the Port Honduras Marine Reserve (no-take zone) have been declining since 2009, falling below 88 conch/ha by 2013, decreasing further to fewer than 56 adult conch/ha in 2014 (Foley 2016, unpublished. cited in, Foley and Takahashi 2017). If queen conch, particularly females, do not have the opportunity to mate and spawn to their full potential, fewer offspring are produced per individual, which is likely to lead to a decrease in the per capita population growth rate (Gascoigne *et al.* 2009). Therefore this is a critical consideration in assessing the sustainability of conch populations. As discussed above, although the observed minimum reproductive density thresholds are highly variable, queen conch populations are recommended to be managed to maintain a threshold density of 100 adult conch/ha (Prada 2017). A density value of 100 adult conch/ha is recommended as a minimum reference threshold for successful reproduction, following a recommendation from the Queen Conch Expert Workshop, held in May 2012 in Miami, Florida (FAO 2012). The Regional Queen Conch Fisheries Management and Conservation Plan (Prada 2017) and the United Nations Environment Programme (UNEP) have both adopted 100 adult conch/ha as the minimum density threshold to avoid significant impacts to recruitment (UNEP 2012). Unfortunately, many queen conch populations do not meet the conditions necessary for successful reproduction and sustainability because adult queen conch densities in most jurisdictions are below 100 adult conch/ha (see *Status of the Population* below).

Population Structure and Genetics

Early studies using allozymes (variant forms of the same enzyme) to examine the genetic structure of queen conch implied high levels of gene flow, but also showed isolated genetic structure for populations either at isolated sites or at the microscale level.

Mitton *et al.* (1989) collected samples from nine locations across the Caribbean including Bermuda, Turks and Caicos, St. Kitts (St. Christopher) and Nevis, St. Lucia, the Grenadines, Bequia Island, Barbados, and Belize, and reported high gene flow as well as genetic differentiation at all spatial scales. For example, they found that queen conch in Bermuda and Barbados were genetically isolated from the rest of the sampled locations. Yet, they also found that conch sampled at two geographically close locations (*i.e.*, Gros Inlet and Vieux Fort) in St. Lucia had significant genetic differentiation despite being separated by only 40 km (Mitton *et al.* 1989). Conch sampled in the United States

(Florida Keys) also demonstrated significant spatial and temporal genetic variation, although genetic similarity among populations was high (Campton *et al.* 1992). Tello-Cetina *et al.* (2005) sampled conch from four sites along the Yucatan Peninsula and reported relatively high levels of intrapopulation diversity and little geographic differentiation, with the population from the Alacranes Reef having the furthest genetic distance from the other three sites.

Several studies conducted in Jamaica reported similar levels of connectivity and genetic differentiation. Blythe-Mallett *et al.* (2021) sampled multiple zones across Pedro Bank, an important commercial fishing ground southwest of Jamaica, and identified two possible subpopulations, one on the heavily exploited eastern end of the bank and another on the central and western end. Pedro Bank is directly impacted by the westward flow of the Caribbean current and could serve as the primary recruitment area of queen conch larvae from upstream locations (Blythe-Mallett *et al.* 2021). Pedro Bank is geographically isolated and receives limited gene flow from mainland Jamaica and other historically important offshore populations within the Jamaican Exclusive Economic Zone (EEZ) (Kitson-Walters *et al.* 2018). The high degree of genetic relatedness within conch sampled from Pedro Bank likely indicates that the populations are sufficiently self-sustaining (Kitson-Walters *et al.* 2018), but still receive larvae from upstream sources that contribute to the population on the eastern end of the bank (Blythe-Mallett *et al.* 2021).

Studies conducted in the Mexican Caribbean have also detected a spatial genetic structure for queen conch populations. Pérez-Enriquez *et al.* (2011) identified a genetic cline along the southern Mexican Caribbean to north of the Yucatan Peninsula, with a reduced gene flow observed between the two most distant locations, representing an increase in genetic differences as geographic distance increased. These authors suggested that since the overall genetic diversity varied from medium to high values, the queen conch had not reached genetic level indicative of a population bottleneck (Pérez-Enriquez *et al.* 2011). Machkour-M'Rabet *et al.* (2017) used updated molecular markers to analyze queen conch from seven sites within the same area and observed similar results with the exception of the apparent genetic isolation of queen conch collected on Isla Cozumel, which was not detected by Pérez-Enriquez *et al.* (2011). The results of this study led Machkour-M'Rabet *et al.* (2017) to conclude that populations of queen conch along the Mesoamerican Reef are not panmictic and demonstrate genetic patchiness indicative of homogeneity among sample areas, providing further evidence for the pattern of isolation by distance.

Márquez-Pretel *et al.* (2013) found four genetic stocks reflecting heterogeneous spatial mosaics of marine dispersion between the San Andres archipelago and the Colombian coastal areas. Queen conch in these areas exhibited an overall deficit of heterozygosity related to assortative mating or inbreeding, potentially leading to a loss in genetic variation (Márquez-Pretel *et al.* 2013).

A broad-ranging spatial genetic study of queen conch across the greater Caribbean using nine microsatellite DNA markers (Truelove *et al.* 2017) found that basin-wide gene flow was constrained by oceanic distance that served to isolate local populations. Truelove *et al.* (2017) genetically characterize 643 individuals from 19 locations including Florida, The Bahamas, Anguilla, the Caribbean Netherlands (*i.e.,* Bonaire, St Eustatius, and Saba), Jamaica, Honduras, Belize, and Mexico, and determined that queen conch do not form a single panmictic population in the greater Caribbean. The authors reported significant differentiation between and within jurisdictions and among sites irrespective of geographic location. Gene flow was constrained by oceanic distance and local populations tended to be genetically isolated.

Recently, Douglas *et al.* (2020) conducted a genomic analysis using single nucleotide polymorphisms from two northeast Caribbean Basin Islands (Grand Bahama to the north and Eleuthera to the south). The authors identified distinct populations on the south side of Grand Bahama Island and the west side of Eleuthera Island potentially due to larval separation by the Great Bahama Canyon. Despite extensive spatial separation of sampled populations around Puerto Rico, Beltrán (2019) concluded that there was little genetic structure in the conch population. However, genetic analyses of four visually characterized phenotypes showed that one morph (designated as Flin) was slightly differentiated from the other phenotypes sampled. Further research into this aspect of queen conch biology is needed to examine the degree of differentiation between phenotypes and to determine if they share the same distribution across the Caribbean region. The results presented in all of these studies provide evidence that variation in marine currents, surface winds, and meteorological events can either promote larval dispersal or act as barriers enhancing larval retention.

Status of the Population

The SRT reviewed data from 39 jurisdictions throughout the species' range and developed several interrelated assessments that were used to inform the status of the queen conch. First, the SRT compiled cross-shelf adult conch density estimates for each jurisdiction in the species' range (see *Density Estimates* below). Second, the SRT developed spatially explicit habitat estimates (see *Conch Habitat Estimate* below) for each jurisdiction. The habitat estimates were necessary for the SRT to be able to estimate total abundance and evaluate population connectivity. Third, the SRT extrapolated each jurisdiction's conch density estimate in the surveyed areas to the jurisdiction's total estimated habitat area to generate population abundance estimates at a jurisdiction-level (see *Abundance Estimates* below). Last, the SRT evaluated population connectivity to elucidate the potential impacts of localized low conch densities on population-wide connectivity patterns (see *Population Connectivity* below). As described above, queen conch reproductive failure has been attributed in many cases to declines in population densities. There are two density thresholds (*i.e.,* <50 adult conch/ha and >100 adult conch/ha) that are well established in the scientific literature and are generally accepted by fisheries managers. The scientific literature indicates that when adult queen conch numbers decline to fewer than 50 adult conch/ha there are significant implications for finding a mate and thus reproductive activity and population growth. When adult queen conch density are reduced to this degree, reproductive activity is limited or non-existent. Along those same lines, the available literature suggests that populations with adult queen conch densities greater than 100 adult conch/ha are sufficient in most cases to promote successful mate finding and thus reproductive activity and population growth. The 100 adult conch/ha density threshold recommendation was prepared by the Queen Conch Expert Working Group (Miami, Florida, May 2012), and subsequently accepted by consensus by fisheries managers participating in the WECAFC /Caribbean Fishery Management Council (CFMC)/Organization of the Fisheries and Aquaculture Sector of the Central American (OSPESCA)/CRFM Working Group, as minimum reference point or "precautionary principle" required to sustain conch populations (Prada *et al.* 2017).

Considering this information, including the best available scientific and commercial information on queen conch reproduction, depensatory processes, and population growth, the SRT applied the following density thresholds to queen conch populations:

- Populations with densities below the 50 adult conch/ha threshold are considered to be not reproductively active due to low adult encounter rates or mate finding. This threshold is largely recognized as an absolute minimum required to support mate finding and thus reproduction.
- Populations with densities between 50-99 adult conch/ha are considered to have reduced reproductive activity resulting in minimal population growth.

- Populations with densities above 100 adult conch/ha are considered to be at a density that supports reproductive activity resulting in population growth.

These density thresholds were used to evaluate the status of queen conch populations in each jurisdiction, and to assess how heterogeneous fishing pressure and localized depletion (*i.e.,* low adult queen conch densities, leading to reduced egg and larval production) effect population connectivity throughout the species' range. The results of these assessments are described in the following sections.

Density Estimates

In order to develop estimates of queen conch density, the SRT conducted a comprehensive, jurisdiction-by-jurisdiction search to identify literature pertaining to the status of queen conch throughout its range. The SRT reviewed the best scientific and commercial information including all relevant published and gray literature, databases, and reports. The SRT organized this information and data by jurisdiction and searched systematically for information on queen conch densities. The SRT also considered relevant information provided during the public comment period (84 FR 66885, December 6, 2019). The SRT's goal was to compile robust, cross-shelf adult queen conch density estimates for each jurisdiction. To the extent possible, the SRT focused on the most recent studies where randomized sampling was conducted across broad areas of the shelf, including a range of habitats and depths. For jurisdictions where such studies were not available, the SRT used available density information. For example, in some cases the only available data were single point estimates from a study or workshop report. For nine jurisdictions where no density information was available (*i.e.,* Curaçao, Costa Rica, Dominica, Grenada, Montserrat, St. Kitts and Nevis, St. Martin, St. Barthelemy, and Trinidad and Tobago), the SRT approximated queen conch density estimates based on density estimates for the nearest neighboring jurisdiction that had information available.

The SRT used available qualitative information on the general population status (*e.g.,* severely depleted, moderately fished, and lightly exploited) to ensure that approximating queen conch densities based on a jurisdiction's nearest neighbor was reasonable (for detailed discussion on methods see Horn *et al.* 2022).

From each study or report compiled, the SRT noted the location, year of the survey (1996 to 2022), total area surveyed, status of the area surveyed (fished or unfished), and the survey methods used (see Table 2 in Horn *et al.* 2022). The SRT extracted information on the overall density or the adult density (or both) of queen conch, and recorded these in a spreadsheet and standardized to a per hectare (ha) unit (see S5 in Horn *et al.* 2022). For jurisdictions with large shelf areas (*e.g.,* The Bahamas, Belize, Mexico) densities were recorded at the sub-jurisdiction level (*e.g.,* as defined by region, bank, or cardinal direction from an island). For smaller jurisdictions (*e.g.,* those within the Lesser Antilles), queen conch densities were typically reported for an entire island or group of islands. The status review report (Horn *et al.* 2022) provides additional detail on how the SRT estimated queen conch population densities.

The adult queen conch density estimates were also plotted by their geographical locations (see Figure 6 in Horn *et al.* 2022). The results revealed that several jurisdictions, mostly located in the north-central to the southwestern Caribbean (*i.e.,* Turks and Caicos, The Bahamas' Cay Sal Bank and Jumentos and Ragged Cays, Cuba, Jamaica, Nicaragua, Costa Rica), tended to have higher adult conch population densities (>100 adult conch/ha) indicating that these populations are reproductively active and are supporting successful population growth. There are a two jurisdictions (*i.e.,* St. Eustatius and St. Kitts and Nevis) within the eastern Caribbean region and a single jurisdiction (*i.e.,* Cayman Islands) in the central Caribbean region, that have moderate adult conch population densities (<100 adult conch/ha, but >50 adult conch/ha). In the eastern Caribbean only two jurisdictions (St. Lucia and Saba) have queen conch densities greater than 100 adult conch/ha. With a few exceptions, the rest of the jurisdictions not previously mentioned above (*i.e.,* Aruba, Anguilla, Antigua and Barbuda, Barbados, Belize, Bermuda, Bonaire, The Bahamas' Western and Central Great Banks and Little Bahama Bank, British Virgin Islands, Colombia's Serranilia and Quitasueno Banks, Curaçao, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Martinique, Mexico, Montserrat, Panama, Puerto Rico, St, Barthelemy, St. Martin, St. Vincent and Grenadines, Trinidad and Tobago, United States (Florida), U.S. Virgin Islands, and Venezuela), have queen conch densities near or below the minimum adult queen conch density threshold (<50 adult conch/ha) required to support reproductive activity. These jurisdictions represent approximately 27 percent (19,626 km^2) of the estimated habitat available in the Caribbean region.

Conch Habitat Estimate

To increase the SRT's understanding of the status of queen conch throughout its range, the SRT estimated conch habitat and prepared a spatially explicit map for the Caribbean region. This spatially explicit conch habitat estimate was necessary in order for the SRT to estimate total abundance and conduct the population connectivity analysis. To develop an estimate of habitat area, the SRT conducted an extensive search for the best available habitat information, including estimated conch fishing bank areas, and contacted researchers and institutions involved in various mapping efforts. The SRT determined that a 0-20 m depth habitat area represented a best estimate because the available information indicates that conch are found in shallow waters generally less than 20 m depth (Berg Jr. *et al.* 1992; Boidron-Metairon 1992; Delgado and Glazer 2020; Salley 1986; Stoner and Sandt 1992; Stoner and Schwarte 1994). The most comprehensive and suitable publicly-available habitat map that could be found was the Millennium Coral Mapping Project, which specifies 1,359 8-km by 8-km polygons based on coral reefs locations (Andréfouët *et al.* 2001). The polygons included seagrass and coral reef locations where queen conch occur (Kough 2019; Souza Jr. and Kough 2020). To ensure that all spawning sites, including deep water spawning sites (*i.e.,* at depths greater than 20 m), were included in the dataset, the SRT verified the habitat map with spawning sites reported in the available literature (Berg Jr. *et al.* 1992; Brownell 1977; Cala *et al.* 2013; Coulston *et al.* 1987; D'Asaro 1965; Davis *et al.* 1984; de Graaf *et al.* 2014; García E. *et al.* 1992; Gracia-Escobar *et al.* 1992; Lagos-Bayona *et al.* 1996; Márquez-Pretel *et al.* 1994; Meijer zu Schlochtern 2014; Pérez-Pérez and Aldana-Aranda 2003; Randall 1964; Stoner *et al.* 1992; Truelove *et al.* 2017; Weil and Laughlin 1984; Wicklund *et al.* 1991; Wilkins *et al.* 1987; Wynne *et al.* 2016).

Following this review, the SRT included 13 additional deep spawning sites for Venezuela, Cuba, The Bahamas, U.S. Virgin Islands, Turks and Caicos, Saba, Colombia, Belize, Honduras, and Jamaica (Brownell 1977; Cala *et al.* 2013; Davis *et al.* 1984; De Graaf *et al.* 2014; Lagos-Bayona *et al.* 1996; Randall 1964; Stoner *et al.* 1992; Truelove *et al.* 2017; Weil and Laughlin 1984; Wicklund *et al.* 1991). The SRT also incorporated 13 shallow polygons not initially present in the dataset for St. Eustatius, U.S. Virgin Islands, Colombia, United States (Florida), Mexico, Jamaica, Saba, Bonaire and The Bahamas (Meijer zu Schlochtern 2014; Randall 1964; Coulston *et al.* 1987; Gracia-Escobar *et al.* 1992; Márquez-Pretel *et al.* 1994, Truelove *et al.* 2017). Overall, the habitat area estimates from the data source selected by the SRT were much lower than total seagrass area estimates, and generally ranged from approximately 30 to 100 percent of the estimated conch fishing banks and incorporated known deep-water spawning sites (see Figure 5 in Horn *et al.* 2022). Thus, the SRT concluded, and we agree, that its habitat estimates were likely conservative, but suitable for analysis of general connectivity patterns and population abundance estimates.

Abundance Estimates

The SRT estimated abundance by extrapolating adult queen conch density estimates across the estimated habitat areas. However, the SRT used these abundance estimates with caution because the available density estimates on which they are based were dated, had sparse data, or were conducted in small areas. In some cases, the number of available surveys with queen conch densities were also limited. For example, the very high estimated queen conch abundance from Cuba is particularly questionable due to the small sample size of survey and the large shelf area over which the survey density data was expanded. Where no survey data were available (*i.e.,* Costa Rica, Curaçao, Dominica, Grenada. St. Kitts and Nevis, St. Barthelemy, St. Martin, Monserrat, and Trinidad and Tobago), density estimates were approximated from the nearest neighboring jurisdiction, and thus their abundance estimates are highly uncertain. The estimated conch habitat areas also introduce some uncertainty in the estimates, and the resolution of the SRT's habitat map is coarse (for additional discussion on methods see Horn *et al.* 2022).

Despite the aforementioned constraints, the SRT estimated jurisdiction-level conch abundance by multiplying available conch density estimates by estimated habitat areas. This approach assumed the range of jurisdiction-level survey-generated conch density estimates is representative of the range of conch densities across the entirety of each jurisdiction's estimated habitat area. When available, multiple surveys were used to better capture the substantial uncertainty inherent in this approach. In jurisdictions where comprehensive surveys were carried out across all areas of the shelf, the mean estimates reported from each survey typically take into account any sub-jurisdiction level variability in conch densities; however, in cases where extrapolations were based on only a few reported density estimates or sampling that was done over a small area, this assumption may be violated. In most studies, conch densities were surveyed across various habitat types (including those types supporting few or no conch) and weighted averages were reported. Thus, those survey means account for areas of both high and low density. The SRT also made efforts to quantify the uncertainty inherent in basing the abundance estimates on surveys that used different methodologies, occurred over a wide time span and over a range of spatial scales. The results suggest that adult queen conch abundance is estimated (*i.e.,* the sum of median estimated abundance across all jurisdictions) to be about 743 million individuals (90 percent confidence interval of 450 million to 1.492 billion). Adult queen conch abundance was estimated to be between ten and 100 million individuals in six jurisdictions, and 15 jurisdictions had median estimated abundances between one and ten million adults. The estimated adult abundance was less than one million adults in each of 20 jurisdictions, with three of those jurisdictions estimated to have populations of fewer than 100,000 adult queen conch. Seven jurisdictions (*i.e.,* Cuba, The Bahamas, Nicaragua, Jamaica, Honduras, the Turks and Caicos Islands, and Mexico) accounted for 95 percent of the population of adult queen conch. Within the species' range, Cuba, The Bahamas, and Nicaragua, are estimated to have the most conch habitat area (56 percent) and the majority of adult queen conch population abundance (84.1 percent). In addition, Jamaica, Honduras, Turks and Caicos, and Mexico are the other major contributors, in terms of both habitat area and conch abundance (see Figures 10, 11, in Horn *et al.* 2022). Twenty-one jurisdictions make up 95 percent of the total estimated conch habitat area, while only seven jurisdictions (i*.e.,* Cuba, the Bahamas, Nicaragua, Jamaica, Honduras, Turks and Caicos, and Mexico) make up 95 percent of the total estimated abundance. This indicates that conch are depleted in many jurisdictions with large habitat areas, and the remaining populations are concentrated in just a few jurisdictions (Horn *et al.* 2022).

Population Connectivity

To elucidate the potential impacts of localized low adult conch densities on population-wide connectivity patterns, the SRT evaluated queen conch population connectivity. The population connectivity model was based on a simulation of the entire pelagic phase of the conch early life cycle, from the hatching of eggs to the settlement of conch veligers in suitable habitats (Vaz *et al*. 2022). This population connectivity evaluation offers insights into how overall exchange of larvae across the species' range has been impacted by overexploitation of adult conch in certain areas. Two sets of simulations were conducted. First, the connectivity patterns were simulated for uniform egg releases across the entire Caribbean region (from 8°N to 37°N and from 98°W to 59°W); this represents an "unexploited spawning" historical density scenario in which all jurisdictions have the same potential for reproductive levels, on a per-area basis. A second simulation of connectivity patterns representing an "exploited" scenario, incorporated realistic localized density patterns by scaling the number of eggs released (on a per-area basis, by jurisdiction or region) by the adult conch densities, and accounts for Allee effects at very low densities (<50 adult conch/ha). Two different hydrodynamic models were used to simulate larvae dispersal through oceanic processes (*e.g.,* oceanic circulation, velocities, sea surface temperatures) (For detailed discussion on methods see Horn *et al.* 2022).

The comparison of the two sets of simulations illustrates the population-level impact of heterogeneous patterns in densities of adult conch (see Figure 12 in Horn *et al.* 2022). The most apparent differences in the two sets of simulations emerged from the fact that many of the jurisdictions had conch densities well below the critical threshold for reproduction (<50 adult conch/ha) and were considered to be reproductively non-viable. Within the "exploited" scenario, the SRT assumed no larvae were spawned from these jurisdictions; subsequently they could only act as sinks (*e.g.,* populations that are not contributing or receiving larvae) for queen conch larvae to settle, but were not sources for themselves or other locations. Connectivity patterns emerging from "exploited" scenario were thus drastically different (see Figure 12 in Horn *et al.* 2022). For example, due to their position up current and their small shelf areas, the Lesser Antilles (*i.e.,* Leeward and Windward Islands) were estimated to be historically important for contributing larval input to other jurisdictions downstream (*i.e.,* to the west). However, due to low adult conch densities in many of these jurisdictions, they are no longer expected to contribute larvae in the "exploited" scenario, resulting in reduced larval input into the Greater Antilles and Colombia.

Other patterns in comparing the "unexploited" versus and "exploited" simulations were more subtle, but would be locally significant. For example, historically the Turks and Caicos Islands were estimated to have received many larvae from the Dominican Republic and Haiti, which would have been important given its low local retention rate (see Figure 12 in Horn *et al.* 2022). However, due to low adult conch densities in these source jurisdictions, the "exploited" scenario suggests that Turks and Caicos Islands are now entirely dependent on local production, and a substantial percentage of larvae are exported to The Bahamas. Likewise, the "unexploited" simulation suggests that the United States (Florida) was dependent on relatively high local retention, with the most significant external source of larvae coming from Mexico (see Figure 12, left column in Horn *et al.* 2022). Both Florida and Mexico are thought to now have very low adult queen conch densities (<50 conch/ha) unable to support any reproductive activity; in other words, Florida currently has no significant upstream or local sources of larvae. This could explain why, despite a moratorium on fishing for several decades, queen conch in Florida waters have been slow to recover (Glazer and Delgado 2020).

The SRT also found that some jurisdictions acted as important "connectors" between different regions of the population as a whole, and could be important for maintaining genetic diversity. The importance of a jurisdiction as a "connector" was quantified mathematically as a Betweenness Centrality (BC) value on a scale of 0 to 1. The BC value measures the relative influence of a jurisdiction's conch reproductive output on the flow of larvae (*e.g.*, larvae dispersed and retained) among jurisdictions range wide. The median of all calculated BC values (approximately 0.05-0.06) was selected to distinguish between high versus low BC values (Vaz *et al.* 2022), which is appropriate given that the BC values are a relative scale of non-normally distributed values. Jurisdictions with high BC values (above the median) act as ecological corridors that facilitate larval flow and are essential to preserve population connectivity. The "unexploited" scenario identified Jamaica, Cuba, and the Dominican Republic as having a high BC value, and to a lesser extent Puerto Rico and Colombia (see Figure 13 in Horn *et al.* 2022). This was not surprising given the relative central location of these jurisdictions and the exposure of their shelves to a diversity of ocean currents, which allows them to be "connectors" of larval flow. In contrast, jurisdictions located at the most up current (*e.g.,* Lesser Antilles) or down current locations (*e.g.*, Florida, Bermuda), or those located at the fringes of the region (*e.g.*, Panama, Bermuda) were not identified as important connectors of larval flow and, as expected, had low BC values (below the median) (see Figure 13 in Horn *et al.* 2022).

Jurisdictions with documented low adult conch densities influenced the estimated connections between jurisdictions when comparing the "unexploited" to "exploited" scenarios. One of the biggest differences was the absence of reproductive output (*e.g.*, larval recruits) from Puerto Rico, Dominican Republic, and Haiti. These jurisdictions had a high BC value (*i.e.*, above 0.05-0.06) under the "unexploited" scenario, but have a low BC value (*i.e.*, below 0.05) under the "exploited" scenario because they no longer function as important connectors (see Figure 13a in Horn *et al.* 2022). An almost complete break in the connectivity between the eastern and western Caribbean region was apparent in the "exploited" scenario, with the Dominican Republic receiving limited larvae from Cuba, Turks and Caicos, and from a deep mesophotic reef off the west coast of Puerto Rico. When those jurisdictions were removed from the chain of larval supply in the "exploited" scenario, Jamaica and Cuba remained important connectors in the western portion of the range, and some of the offshore banks in Colombia remained functional connectors (see Figure 13 in Horn *et al.* 2022). While Vaz *et al.* (2022) indicates that connections have been lost in several locations due to the existence of low adult conch densities, points of connection likely still exist, albeit reduced, which allow some exchange of larvae and maintenance of some genetic diversity.

Localized patterns of conch overfishing can also influence genetics. The SRT estimated genetic distance between jurisdictions and then compared those to a Caribbean-wide genetic study (Vaz *et al.* 2022; Truelove *et al.* 2017). The "unexploited" scenario corresponded well to the patterns observed by Truelove *et al.* (2017) given that larvae within each region identified by the Truelove *et al.* (2017) were most likely locally originated. The exception was the high probability of larval exchange between The Bahamas and Turks and Caicos Islands and the Greater Antilles (see Figure 12 in Horn *et al.* 2022). In the "exploited" scenario, six of the 12 jurisdictions sampled by Truelove *et al.* (2017) were not reproductively active (Vaz *et al.* 2022). Due to the lack of spawning, it was expected that not all connectivity patterns could be reproduced. Indeed, in this case, the high self-settlement observed for Mexico, Belize, and Florida was absent due to the lack of reproductive activity (Vaz *et al.* 2022). Subsequently, the genetic evaluation focused only on the results of the "unexploited" scenario since the results of the "exploited" scenario were insignificant due to the reduced number of data points (*i.e.*, jurisdictions). The results suggest that queen conch populations exhibit an isolation-by-distance pattern (Vaz *et al.* 2022).

Summary of Factors Affecting Queen Conch

As described above, section 4(a)(1) of the ESA and NMFS' implementing regulations (50 CFR 424.11(c)) state that we must determine whether a species is endangered or threatened because of any one or a combination of the following factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. The SRT summarized information regarding each of these threats according to the factors specified in section 4(a)(1) of the ESA. We conclude the SRT's findings with respect to the ESA section 4(a)(1) listing factors are well-considered and based on the best available scientific information, and we concur with their assessment. Available information does not indicate that destruction, modification or curtailment of the species' habitat or range and disease or predation are operative threats on this species; therefore, we do not discuss those further here. More details with respect to the available information on these topics can be found in the status review report (Horn *et al.* 2022). This section briefly summarizes the SRT's findings regarding the following factors: overutilization for commercial, recreational, scientific, or educational purposes, inadequacy of existing regulatory mechanisms; and other natural or manmade factors affecting its continued existence.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Description of the Fishery

Queen conch have been harvested for centuries and are an important fishery resource for many nations in the Caribbean and Central America. The most common product in trade is queen conch meat. The FAO landings data indicate that the total annual landings in 2018 (most recent year data are available) for all jurisdictions is estimated to be 33,797 metric tons (mt) (see S1; Horn *et al.* 2022). Prada *et al.* (2017) estimated production of queen conch meat for most jurisdictions is approximately 7,800 mt annually. However, total conch production is difficult to estimate because of incomplete and incomparable data across jurisdictions (Prada *et al.* 2017). The majority of the queen conch meat is landed in Belize, The Bahamas, Honduras, Jamaica, Nicaragua, and Turks and Caicos. In the artisanal fishery, queen conch are sometimes landed with the shell, but mostly as unclean meat with the majority of organs still attached. Additionally, local markets and subsistence fishing of queen conch is often not monitored or not included in catch data. In some jurisdictions, the subsistence and locally marketed catches are small, but they can be high in some jurisdictions (Prada *et al.* 2017). Furthermore, the best estimates of unreported catch and illegal harvest is most likely an underestimate, yet accounts for about 15 percent of total annual catch (Horn *et al.* 2022; Pauly *et al.* 2020). Queen conch meat production shows a negative trend over time and the decrease can largely be attributed to overfishing (Prada *et al.* 2017). Some stocks have collapsed and have yet to recover (Theile 2005; Aldana-Aranda *et al.* 2003; Appeldoorn 1994b).

Queen conch shells are also used as curios and in jewelry, but are generally of secondary economic importance. Shells may be offered to tourists in its natural or polished form (Prada *et al.* 2017). The large pinkish queen conch shells are brought to landing sites in only a few places. In most cases, shells are discarded at sea, generating several underwater sites with piles of empty conch shells. According to Theile (2001) from 1992 to 1999, a total of 1,628,436 individual queen conch shells, plus 131,275 kg of shells were recorded in international trade. Assuming that each queen conch shell weighs between 700 and 1500 g, the total reported volume of conch shells from 1992 to 1999 may have been equivalent to between 1,720,000 and 1,816,000 shells (Prada *et al.* 2017). In addition, queen conch pearls are valuable and rare, but their production and trade remain largely unknown across the region. In Colombia, one of the few jurisdictions with relevant data, exports of 4,074 pearls, valued around USD 2.2 million, were reported between 2000 and 2003 (Prada *et al.* 2009). With the reduction of the fishing effort in Colombia, the number of exported queen conch pearls declined from 732 units in 2000 to 123 units in 2010 (Castro-González *et al.* 2011). Japan, Switzerland, and the United States are the main queen conch pearl importers (Prada *et al.* 2017). Lastly, in recent years, operculum trade has developed, but similarly little is known about it. China is the major importer and it is believed opercula are used in traditional Chinese medicine. In 2020, the U.S. Fish and Wildlife Service (USFWS) confiscated a shipment in-transit from Miami, Florida to China (weighing 1 mt) of conch products, consisting largely of opercula. The shipment was confiscated by USFWS for CITES and U.S. Lacey Act violations (GCFINET, June 10, 2020).

Indications of Overutilization

In broad terms, a sustainable fishery is based on fishing "excess production" and supported by a stable standing stock or population. In a sustainable fishery, the abundance of the fished population is not diminished by fishing (*i.e.,* new production replaces the portion of the population removed by fishing). Under ideal conditions, the age structure of a fished population is also stable, for example, without truncation of the largest, most productive members of the population. There are a variety of indications when a fishery resources is overutilized. Declines in fishing catches or landings with the same amount of fishing effort (*i.e.,* CPUE) can indicate a population is being over-utilized. Similarly, changes in spatial distribution (*e.g.,* depletions near fishing centers or depletions in more easily accessible shallow water habitats) likely indicate overutilization. Additionally, a reduction of genetic diversity or a reduction in maximum size achieved can indicate severe overutilization. Drastic differences between population densities found in protected, non-fishing reserves and those found in fishing areas can also indicate overutilization, even though the reserve may serve to moderate the effects of overutilization to a certain extent. These factors were all considered in the SRT's assessment of the threat and impact of overutilization on the status of the queen conch. Reductions in distribution as well as overall population levels can be especially problematic for queen conch because they require a minimum local adult density to support reproductive activity.

In particular, available density estimates provide an initial indication that queen conch may be suffering from overutilization. Approximately 25 (of 39) jurisdictions have adult conch densities below the minimum cross-shelf density (50 adult conch/ha) at which reproductive activity largely ceases. It should be noted, however, that this minimum density pertains to density within reproductive populations and not necessarily cross-shelf densities. Overall, however, the available data suggest that queen conch has been significantly depleted throughout its range with only a few exceptions. The jurisdictions of Saba, St. Lucia, Colombia's Serrana Bank, Nicaragua, Jamaica's Pedro Bank, Costa Rica, Cuba, The Bahamas' Cay Sal Bank and Jumentos and Ragged Cays, and Turks and Caicos are the only jurisdictions that have cross-shelf densities above the 100 adult conch/ha threshold to support reproductive activity resulting in population growth discussed above. It is likely that populations residing in inaccessible areas (difficult to fish) may support some level of mating success and therefore recruitment. However, in these jurisdictions surveys are not comprehensively performed, and there is evidence of local overutilization of some populations.

The Landings Data

The SRT evaluated landings data from two international databases. The FAO maintains data supplied by member nations in their FishStat database. The queen conch data represent the landings of commercial fisheries, generally artisanal and industrial, in the Western Tropical Atlantic; however, discussions are continuing among scientific working groups regarding the inadequacy and inconsistency of reporting in this database (FAO Western Central Atlantic Fishery Commission 2020). For example, the reports from each jurisdiction vary depending on how much processing has been done (FAO Western Central Atlantic Fishery Commission 2020). Data are reported either in live weight, which equates to whole animals, or in various grades of cleaned weight (*e.g.,* dirty conch (unprocessed, removed from shell), 50 percent (operculum and viscera removed), 65 percent (operculum, viscera, and "head" (*i.e.,* eyes, stalks, and proboscis) removed), 85 percent (all of the above plus verge, mantle, and part of the skin removed) and 100 percent cleaned (fillet, *i.e.,* only the pure white meat remains)). The types of submitted landings have not always been clearly defined and there is a continuing effort to encourage jurisdictions to submit consistent queen conch fisheries data and use standardized conversion factors so data from different reports can be compared more reliably (FAO Western Central Atlantic Fishery Commission 2020).

Additional complications in interpreting FishStat data relate to unexplained changes in local conditions or influences on the fisheries. Interannual changes in landings may be due to changes in availability of queen conch (*i.e.,* lowered CPUE), but they may also be due to changes in regulations or enforcement or unfavorable environmental conditions (*e.g.,* hurricane disruptions of fishing). Without some concomitant data on fishing effort, it is difficult to interpret changing landings.

The second international repository of conch data is maintained by the CITES. The CITES database records exports and imports of internationally traded queen conch. The CITES data do not include commercial catches for local markets and can suffer from many of the same shortcomings as the FAO FishStat data. Neither database includes spatial information that allows analysis of local effects on populations. In addition to providing data for international obligations, most jurisdictions have widely varying capabilities for collecting complete data that would adequately characterize all fishing sectors. They primarily have focused on commercial fishing, either industrial or artisanal. Jurisdictions have typically inadequately recorded data from the artisanal commercial fishing sector since landing sites can be too numerous to effectively monitor with the limited number of fishing inspectors employed, and self-reporting is often incomplete. Generally, information is lacking from most jurisdiction throughout the Caribbean region on recreational or subsistence fishing, which includes sectors that generally fish for personal consumption, as well as minor sales or barter of catches. Gaps also occur in some data collected on catches destined for local consumption, either by family, neighbors or restaurants. An additional complication with interpreting ecological and fishery independent data is that different metrics tend to be used. Commercial landings are reported in weight and ecological surveys typically count numbers and estimate or measure lengths of queen conch. Conversion factors may be jurisdiction- or site-specific, so comparing reported landings to density surveys has inherent difficulties and opportunities for miscalculation.

In an effort to fill the gaps in total reported queen conch landings, the SAU program (Fisheries Centre, Univ. of British Columbia, *www.seaaroundus.org*) developed a protocol to reconstruct landings histories for most of the jurisdictions where queen conch is fished. The SAU scientists assembled available data on landings, supplemented with additional sociological and fishing data and identified alternative information sources for missing data by consulting with local experts and additional literature, to produce their best estimates of total landings from all fishing sectors. The SAU data includes subsistence fishing, recreational fishing, and small-scale artisanal fishing that are generally poorly documented by other sources. For these reasons, the SRT concluded the SAU data are the most comprehensive and is the best available data for understanding the magnitude and impact of all fishing pressure including subsistence, recreational, and artisanal fishing on local stocks of queen conch. The SRT compared the reconstructed landings from the SAU project (Pauly *et al.* 2020) to the reported FAO landings for queen conch in the western Caribbean to examine the magnitude of potential differences (see Figure 14 in Horn *et al.* 2022). Based on this comparison, early reports of FAO landings were greatly underestimated. From 1950-59, unreported landings averaged 93.8 percent of the total SAU-reconstructed queen conch landings (see Figure 14 in Horn *et al.* 2022). For regional landings, the mean percent of unreported landings varied in each decade, 1960-69: 72.1 percent, 1970-79: 53.0 percent, 1980-89: 42.0 percent, 1990-99: 15.8 percent, 2000-09: 23.0 percent, 2010-16: 23.7 percent. Since about 1990, there were improvements in the correlation between FAO and the SAU-reconstructed landings (ranging from 15-25 percent unreported), but the FAO landings are unlikely to include all of the fishing sectors in each jurisdiction, for the reasons discussed above.

To provide a more meaningful comparison with population estimates, the SAU-reconstructed landings were converted to estimated abundance. For this region-wide comparison, a standard regional conversion factor was used (live weight: 1.283 kg/individual, Thiele 2001); subsequent analyses for specific jurisdictions used location-specific conversion factors where available. When no jurisdiction or site-specific information was available, the SRT used the same standard regional conversion factor. At the peak, regional landings translated into about 32-33 million queen conch per year and, after a slight dip in 2005-2006, landings remained about 30-31 million queen conch per year from 2012-2016, which is the most recent years with complete data (see Figure 14 in Horn *et al.* 2022). Repeatedly in the reports of SAU-reconstructed landings, the landings are stated as conservative, underestimating the likely actual landings. The information cited by the SRT (see S1 in Horn *et al.* 2022) also provides evidence that many jurisdictions are landing significant amounts of juvenile or sub-adult conch, which would be expected to weigh less than 1.283 kg/individual, thus, the converted abundance figures should also be considered an underestimation.

The SRT chose to use the SAU-reconstructed landings, when available, as the best estimate of total landings and used them to compare exploitation rates (*e.g.,* individuals removed) and stock size estimates. If SAU-reconstructed landings data were not available, the SRT used FAO landings data for the comparisons. These data give some indication of the full magnitude of fishing on queen conch across the species' range. The mean landings per year from 1950-2016 show that the 12 highest producing jurisdictions have produced 95 percent of the landings across the region (*i.e.,* Turks and Caicos, The Bahamas, Honduras, and Jamaica, followed by Belize and Nicaragua, and then Dominican Republic, Mexico, Cuba, Antigua and Barbuda, Colombia, and Guadeloupe).

Estimates of Exploitation Rate

Traditional fishery stock assessments use fishery landings data and indices of relative stock abundance to determine exploitation rates. However, few jurisdictions collect adequate information (*e.g.,* catch-per-unit effort data, landings data encompassing all removals) from their queen conch fisheries to develop traditional stock assessment models and associated recommendations for sustainable harvest. An alternative metric using a combination of landings and density surveys has been recommended by expert working groups and fisheries managers to estimate exploitation rates. Using this alternative metric, the working groups and fisheries managers recommend limiting fishing to no more than 8 percent of mean or median fishable biomass (*i.e.,* standing stock) as a precautionary sustainable yield, if the stock density can support successful reproduction (*i.e.,* 100 adult conch/ha) (FAO Western Central Atlantic Fishery Commission 2013). The 8 percent exploitation target seeks to ensure that the population per capita growth rate exceeds the exploitation rate, which in turn ensures population sustainability under controlled harvest. Using exploitation rates as a proxy for sustainable yield targets uses fishery-independent estimates of abundance and fishery-dependent landings data as a substitute for full stock assessments in data-poor fisheries. Additionally, using exploitation rates as a proxy depends on statistically valid sampling to ensure that population extrapolations are an accurate indicator of population status. This approach also depends on quantifying or mapping depths and habitats on which to base extrapolations. The FAO also recommends that the 8 percent exploitation rate be adjusted downward if the mean conch density is below the level required to support successful reproductive activity (100 adult conch/ha) (FAO Western Central Atlantic Fishery Commission 2013).

In an effort to better understand whether adult conch densities can support current exploitation rates, the SRT plotted the estimated adult conch densities against recent landings (maximum of either FAO or SAU) to evaluate regional trends in resource usage (see Figures 18, 19 in Horn *et al.* 2022). Exploitation rates for each jurisdiction were calculated by the SRT as the average numbers landed per year divided by the total abundance (adults only) across the shelf for the period 2010-2018 (For additional information on methods, see Horn *et al.* 2022). The SRT's analysis suggests that the highest producers in the region, Dominican Republic, Antigua and Barbuda, Belize, Turks and Caicos, and Mexico, significantly exceed the 8 percent exploitation rate target. Additionally, of these jurisdictions, all but Turks and Caicos, have adult conch densities below the absolute minimum adult density (*i.e.,* 50 adult conch/ha) required to support any level of reproductive activity. The fact that these jurisdictions have exceeded the 8 percent exploitation rate, have adult conch densities below 50 adult conch/ha, and have not lowered the exploitation rate, indicates harvest is unsustainable and overutilization is likely occurring. Nicaragua, Honduras, and Jamaica are fishing near the 8 percent exploitation rate target. However, while Honduras fishes near the 8 percent exploitation rate, the adult conch densities are also below the minimum density threshold (50 adult conch/ha), which also indicates that harvest is unsustainable and overutilization is likely occurring. The majority of other conch meat producers within the Caribbean region (*e.g.,* St. Vincent and the Grenadines, Puerto Rico, Panama, Guadeloupe, Anguilla, St. Lucia, St. Kitts and Nevis, St. Barthelemy, St. Martin, Curaçao, U.S. Virgin Islands, and Haiti), are fishing well above the 8 percent rate and their adult conch densities are well below the minimum density threshold (50 adult conch/ha), indicating overutilization is likely occurring. Notably, Aruba, Barbados, Colombia, The Bahamas, Bonaire, British Virgin Islands, Martinique, Venezuela, and Grenada, all fish below the 8 percent exploitation rate, but also have very low adult densities (<50 adult conch/ha), which suggests that these populations are experiencing recruitment failure due to depensatory processes, despite the low exploitation rate.

Summary of Findings

Queen conch has been fished in the western tropical Atlantic for hundreds of years, but in the last four decades, fishing has increased and industrial scale fishing has developed (CITES 2003). In most jurisdictions, conch fishing continues although population densities are very low, with conch populations either experiencing reduced reproductive activity or having densities so low that reproductive activity has ceased.

Several indicators suggest that overfishing is affecting abundances, densities, spatial distributions, and reproductive outputs (FAO 2007). In addition, many jurisdictions cite the loss of queen conch from shallow waters and the need for their fisheries to pursue conch with SCUBA or hookah in deeper waters (see S1 in Horn *et al.* 2022).

Efforts to assess the status of queen conch across its range are hampered by the lack of data collection for all fishing sectors. While many jurisdictions make an effort to collect data on the main commercial fisheries, including both industrial and artisanal, the collections are difficult in artisanal conch fisheries. Artisanal fisheries typically land queen conch at a wide variety of locations, lack adequate centralized marketing outlets that can be monitored as a check on landings, and lack enforcement resources to ensure compliance with size, quotas, and other regulations. To cope with the short-comings of data collection, the SAU project implemented an approach to reconstruct catches for most of the jurisdictions where queen conch is fished. The SRT relied on these reconstructed landings as best available scientific information to examine changes in landings over time and comparisons of landings with standing stock.

The results from the SRT's analysis provide substantial evidence indicating that overutilization is occurring throughout the species' range. Only 10 percent (4 jurisdictions) of the 39 jurisdictions reviewed are fishing at or below the 8 percent exploitation rate and have adult conch densities that are capable of supporting successful reproduction (>100 conch/ha), and therefore recruitment (Horn *et al.* 2022). Forty-one percent of the jurisdictions reviewed are exceeding the 8 percent exploitation rate and have a median conch densities below the 100 adult conch/ha threshold required for successful reproductive activity, while 33 percent of the jurisdictions reviewed are exceeding the 8 percent exploitation rate and have median conch densities below the minimum threshold required to support any reproductive activity (<50 adult conch/ha). Thus, the best available commercial and scientific information indicates that exploitation levels have resulted in the overutilization of the species throughout its range and represents the most significant threat to species.

Inadequacy of Existing Regulatory Mechanisms

The SRT evaluated each jurisdiction's regulations specific to queen conch, including fisheries management, implementation and enforcement, to determine the adequacy of existing regulatory mechanisms in controlling the main threat of overutilization of the species throughout its range. The SRT identified some common minimum size regulations that are intended to restrict legal harvest with some form of size-related criterion. The general goal of the size restrictions is to offer protection to at least some proportion of queen conch (*e.g.*, juveniles or immature conch) that are not yet sexually mature to preserve reproductive potential. A more detailed summary that includes the best available information on queen conch populations, fisheries, and their management in each jurisdictions is presented in its entirety in the status review report (see S1 in Horn *et al.* 2022).

Common Queen Conch Minimum Size Regulations

Minimum size regulations are often implemented to help prevent the harvest of juvenile or immature conch. These minimum size requirements rely on lip thickness, lip flare, shell length, and meat weight as indicators of maturity.

Lip thickness is the most reliable indicator for maturity in queen conch. The best available information indicates that shell lip thickness for mature queen conch ranges from 17.5 to 26.2 mm for females, and 13 to 24 mm for males (Stoner *et al.* 2012; Bissada 2011; Aldana-Aranda and Frenkiel 2007; Avila-Poveda and Barqueiro-Cardenas 2006). Boman *et al.* (2018) suggested that a 15 mm minimum lip thickness would be appropriate for most of the Caribbean region. The primary goal of a minimum lip thickness is that queen conch will have at least one season after reaching sexual maturity to mate and spawn. However, many of the lip thickness requirements discussed below are set too low to ensure the maturity of the harvested conch.

Regulations that simply require a flared lip to be harvested are based on a long-outdated idea that maturity occurs at the time of the flared lip develops (Stoner *et al.* 2021). Flared shell lips are an unreliable independent indicator of maturity because as discussed above, the shell lip can flare a full reproductive season before an individual can mate or spawn. Similarly, it is well established that shell length is a poor predictor of maturity in queen conch because maturity occurs following the termination of growth in shell length, and final shell length is highly variable with location and environmental conditions (Tewfik *et al.* 2019; Appeldoorn *et al.* 2017; Foley and Takahashi 2017; Stoner *et al.* 2012c; Buckland 1989Appeldoorn 1988a).

Moreover, regulations that impose shell requirements (*e.g.*, shell length, flared lip or lip thickness) are not enforceable if the shell is discarded at sea and the conch can be landed out of its shell. Meat weight is the only maturity measure not associated with the shell and it is also not a reliable criterion of maturity in queen conch. As previously discussed, large immature conch can have larger shells (sometimes with a flared lip) and weigh more than adults. Further, meat weight requirements that are enforced after the animal is removed from its shell have reduced effectiveness in limiting the harvest or protecting reproductive potential because the animal cannot be returned.

Bermuda

Queen conch were relatively abundant in Bermuda up until the late 1960s, but by the late 1970s populations had reached very low levels (Sarkis and Ward 2009). Bermuda subsequently closed the queen conch fishery in 1978 and queen conch is currently listed as endangered under the Bermuda Protected Species Act 2003. The Bermuda Department of Conservation Services has developed a recovery plan for queen conch with the primary goal to promote and enhance self-sustainability of the queen conch in Bermuda waters. Despite closure of the fishery over 40 years ago, adult densities across the shelf remain low (and below the 50 adult conch/ha required to support any reproductive activity) suggesting additional regulations or management measures, such as those aimed at protecting local habitat or water quality, may be warranted. The SRT's connectivity model (Vaz *et al.* 2022) indicates that the queen conch population in Bermuda relies entirely on self-recruitment. Thus, without management or regulatory measures that not only protect, but also help grow the adult breeding population, queen conch densities will likely decline in the future.

Cayman Islands

Concerns about overfishing of queen conch in the Cayman Islands began in the early 1980s, and in 1988 the Department of Environment began conducting surveys to monitor the status of queen conch. Available survey data indicate persistently low queen conch densities from 1999 to 2006; followed by a decline in 2007 and a modest increase in 2008 (Bothwell 2009). The Cayman Islands import the majority of their conch meat, but there is a small fishery that harvests queen conch for domestic consumption (Bothwell 2009). The Cayman Islands' 1978 Marine Conservation Law established a closed fishing season (May 1 through October 31), during which no conch may be taken from Cayman waters, and a 5 conch per person or 10 conch per vessel per day bag limit during the open season. Queen conch fishing is prohibited in Marine Park Replenishment Zones. There are no minimum size regulations to prevent harvest of juvenile conch. The use of Self-Contained Underwater Breathing Apparatus (SCUBA) and hookah diving gear to harvest marine life is prohibited in the Cayman Islands (Bothwell 2009; Ehrhardt and Valle-Esquivel 2008). Local Illegal, Unreported, Underreported (IUU) fishing is a significant issue and regularly occurs in protected areas by neighboring countries (Bothwell 2009). Given the Caymans' small shelf area, Bothwell (2009) concluded that even a single poacher, who requires only simple fishing gear (*i.e.,* mask and fins), can cause severe problems. In addition to local illegal fishing, the Cayman Islands also receive IUU queen conch meat fished or exported from neighboring jurisdictions, and border control has been identified as a severe weakness (Bothwell 2009). The SRT's connectivity model indicates (Vaz *et al.* 2022) that the Cayman Islands are largely a source for queen conch larvae to other jurisdictions (particularly Cuba), so as queen conch in the Cayman islands are depleted, other jurisdictions are less likely to receive recruits from the Cayman Islands (see Figure 12 in Horn *et al.* 2022). Given the persistently low queen conch densities over the last decade, lack of minimum size regulations to prevent juvenile harvest, lack of enforcement, and evidence of significant IUU fishing, existing regulatory measures within the Cayman Islands are likely inadequate to protect queen conch from overutilization and further decline in the future.

Colombia

The queen conch commercial fishery in Colombia shifted to the continental shelf Archipelago of San Andrés, Providencia, and Santa Catalina (ASPC), including its associated banks (Quitasueño, Serrana, Serranilla, and Roncador) in the 1970s when conch populations in San Bernardo and Rosario became severely depleted due to inadequate regulatory mechanisms (Mora 1994). Even with the declaration of San Bernardo and Rosario as national parks that allow subsistence fishing only, densities further declined to very low levels by 2005 (0.9–12.8 adult conch/ha, 0.2–12.9 juvenile conch/ha), suggesting recruitment failure (Prada *et al.* 2009). Prada *et al.* (2009) noted that illegal queen conch harvest might represent 2–14 percent of total harvest (approximately 1.4–21.8 mt of clean meat). During the 1980s and 1990s, a suite of regulatory measures was put in place to protect populations in the ASPC because it constituted almost all of Colombia's production. Regulations include area closures, prohibition on the use of SCUBA gear, a minimum of 225 g meat weight, and a minimum of 5 mm shell lip thickness (Prada *et al.* 2009). In addition, the CITES listing in 1992 established international trade rules. Despite these measures, fishery-dependent data collected through the mid-1990s and early 2000s masked continued population declines due to biases associated with reporting CPUE, incomplete data reporting (*e.g.,* inconsistent reporting of landings in versus out of the shell and incomplete or absent key spatial information), and illegal trade both into and out of Colombia. For example, in 2008, illegal queen conch meat exports were traced back to Colombia (as well as other jurisdictions previously mentioned) during the Operation Shell Game investigation (U.S. House, Committee on Natural Resources, 2008). Ultimately, management measures were ineffective as evidenced by decreased landings, increased effort, and low densities reported by diver-based visual surveys at two of the three offshore banks: 2.4 conch/ha at Quitasueño and 33.7 conch/ha at Roncador (Valderrama and Hernández, 2000). The Colombian government responded by closing the fisheries at Serrana and Roncador, and reducing the export quota by 50 percent (CITES 2003). Still these measures were inadequate and the entire ASPC closed from 2004–2007 due to illegal trade, conflicts between industrial and artisanal fishers, and discrepancies between landings and exports (Castro-González *et al.* 2009). In 2008 the fishery at ASPC partially reopened at Roncador and Serrana Banks, with annual production set at 100 mt (Castro-González *et al.* 2011), only to close the fishery at Serrana Bank again in 2012.

The overall adult queen conch densities remain below the critical threshold required to support any reproductive activity throughout much of the jurisdiction. Despite very low adult densities (fewer than 50 adult conch/ha in all locations, except at Serrana bank), the queen conch fishery continues to operate in Colombia. Because the ASPC is unlikely to receive significant larval input from source populations outside the area (Vaz *et al.* 2022), the region may not recover with current regulatory measures without sufficient adult densities in local populations. The lack of information for populations in deeper areas throughout the ASPC, which may be particularly important for recovery (Castro *et al.* 2011 unpublished), hinders Colombia's ability to make comprehensive management decisions and illegal fishing continues to plague the region. Furthermore, while regulations require a minimum shell lip thickness of 5 mm and shell lip thickness is a reliable indicator for maturity in queen conch, this value is likely too low to protect immature queen conch harvest. Finally, when the shell is discarded at sea the lip thickness requirement is not enforceable, and any protective value of the meat weight regulations is diminished.

Costa Rica

Queen conch harvest in Costa Rica was prohibited in 1989 (CITES 2003; Mora 2012). In 2000, the commercial sale of incidentally captured queen conch was also prohibited, but queen conch caught as bycatch could be kept for personal consumption. Population declines were reported in 2001, but there is limited information available related to those declines (CITES 2003). The adequacy of existing regulatory measures in protecting queen conch from threats, such as IUU fishing is unknown.

Cuba

The current status of queen conch populations in Cuba is questionable due to a lack of available information; however, the few published surveys suggest relatively high densities, particularly in protected national parks (*e.g.,* Jardines de la Reina National Park: 1,108 conch/ha in 2005; Formoso *et al.* 2007; National Park Desembarco del Granma: 511 conch/ha to 1,723 conch/ha in 2009 to 2010; Cala *et al.* 2013). The SRT was unable to locate more recent population assessments or surveys. The commercial harvest of queen conch began in Cuba in the 1960s and the harvest level increased considerably in the mid to late 1970s. However, due to the largely unregulated and unmanaged harvest, the queen conch population collapsed, and the fishery was closed in 1978. It reopened in the 1982 with a 555 mt harvest quota, which increased to 780 mt in 1984 (Munoz *et al*. 1987). Conch populations continued to decrease at an accelerated rate despite the newly established quota system and size based regulations (Grau and Alcolado as cited in Munoz *et al.* 1987). Munoz *et al.* (1987) attributed the continued population declines to harvest quotas being set too high and illegal harvest. In 1998 the fishery was closed again for a year to conduct an abundance survey (Formoso 2001) and update quotas. Since then, the queen conch fishery has been managed under a catch quota system that is established by "zones" and set between 15 and 20 percent of the adult queen conch biomass, according to population assessments and monitoring. The most recent FAO landings data indicates that queen conch landings have ranged from 475 mt landed in 2018, 405 mt in 2017, and 477 mt in 2016 (see S2 in Horn *et al.* 2022); however, no population assessments or surveys were available for these years. The regulations also include seasonal closures that co-occur with peak spawning, depth limits on diving operations, a prohibition on SCUBA gear, and a minimum lip thickness of greater than 10 mm. While shell lip thickness is a reliable indicator for maturity in queen conch, the minimum 10 mm shell lip thickness regulation likely does not prevent the harvest of immature queen conch. Additionally, compliance and enforcement of these regulations appears to be a problem. For example, two fishing “zones” were closed in 2012 because fishermen were not complying with the regulatory requirements (FAO Western Central Atlantic Fishery Commission 2013).

Despite the lack of available information on illegal harvest of conch in Cuba, there is evidence that some limited illegal conch harvest likely occurs. A recent news article estimated that around one thousand vessels involving approximately 2,500 people were engaged in the illegal harvest of marine species, including conch, lobster, and shrimp (14ymedio 2019). In 2019, Cuba passed new fishery laws aimed at curbing illegal fishing by instituting a new licensing system (14ymedio 2019). There is currently no information available on the implementation and enforcement of these new regulations, and the only survey data available are from surveys of protected areas in 2009. In addition, Cuba’s regulations are meant to implement a catch quota system that is based on adult biomass estimates, which are obtained through population assessment, and the most recent population assessments available are more than 10 years old. Without additional information on the status of the queen conch population in Cuba or the effectiveness of the new regulations, the adequacy of existing regulations is unknown. However, given the history of the conch fishery, including the rate at which declines can occur with unsustainable quotas, and the rate of illegal harvest, effective enforcement of existing regulations, particularly in the protected areas, is important to protect the queen conch in Cuba from overutilization in the future.

Dominican Republic and Haiti

Queen conch in the Dominican Republic and Haiti have been overfished since the 1970s (Wood 2010; Mateo Pérez and Tejeda 2008; Brownell and Stevely 1981). In 2003, Haiti established regulations that include a ban on harvesting queen conch without a flared lip, and the use of SCUBA and hookah gears (CITES 2003). However, the available information indicates that queen conch are still fished in Haiti using SCUBA gear (FAO 2020; Wood 2010). Similarly, while the regulations for a closed season from April 1 through September 30 exist, the available information indicates that enforcement is limited (FAO 2020).

The Dominican Republic established regulations for a minimum shell size in 1986, a closed season in 1999, and no fishing areas in 2002. But these regulations are reported to be ineffective due to inadequate enforcement (CITES 2003, 2012). Illegal trade is also common. For example, from 1999 to 2001, the Dominican Republic almost doubled its queen conch production, elevating concerns about illegal fishing, which resulted in the imposition of a CITES moratorium. More recently, in 2008, both Haiti and the Dominican Republic, in addition to Jamaica, Honduras, and Colombia, were implicated in illegal exports of more than 119 mt of queen conch meat during the Operation Shell Game investigation (Congress, U.S. House, Committee on Natural Resources, 2008).

Although dated (*i.e.,* more than 10 years old), the available information indicates that adult queen conch densities are below the minimum density threshold for any reproductive activity (50 adult conch/ha). The status of queen conch in the Dominican Republic is concerning because under historical conditions it likely functioned as an important ecological corridor, facilitating species connectivity throughout the region (Vaz *et al.* 2022). Although there is evidence that the rates of decline may have slowed in some areas since 2000 (Torres and Sullivan-Sealey 2002) and that some locations have reproductive activity (Wood 2010), there is no evidence that regulations have been effectively implemented or enforced (CITES 2003, 2012; Wood 2010; Figueroa and González 2012). In addition, detailed, accurate, consistent, and unbiased reporting of fisheries data is a challenge and creates a barrier to recognizing and understanding the current status of populations (FAO Western Central Atlantic Fishery Commission 2020). Thus, the SRT concluded that adult queen conch densities are well below what is required for healthy spawning populations at most locations (Posada *et al.* 1999; Wood 2010) and continued declines may be irreversible without human intervention even if fishing pressure is significantly reduced or halted (Torres and Sullivan-Sealey 2002). Based on the foregoing, existing regulations are likely inadequate to address the threat of overutilization and reverse the decline of populations in the Dominican Republic and Haiti.

Jamaica

Jamaica has been a major producer for the queen conch fishery since the 1990s (Aiken *et al.* 1999; Appeldoorn 1994a; Prada *et al.* 2009). The commercial fishery is focused around Pedro Bank, located approximately 80 km southwest of Jamaica. Fisheries-independent diver-based surveys began on Pedro Bank in 1994 and these surveys have helped establish total allowable catch (TAC) limits for the fishery. Queen conch surveys are conducted about every 3 to 4 years (*e.g.,* 1994, 1997, 2002, 2007, 2011, 2015, and 2018). Queen conch density estimates for all life stages and depth strata from 1994 to 2018 have remained at a level that supports successful reproductive activity (142-203 conch/ha; NEPA 2020). However, surveys in 2018 recorded low enough densities (203 conch/ha, age classes was not provided) such that the National Fisheries Authority of Jamaica implemented a closure of the queen conch fishery from 2019 to

2020. Due to the lack of funding to conduct a new survey, the closure was extended to February 2021 (Jamaica Gleaner, Ban on Conch Fishing Extended to February 2021, April 6, 2020).

In 1994 the queen conch fishery management plan established guidelines for management measures including a national TAC and individual quota system (Morris 2012), a closed commercial season generally extends from August 1 through February 28 (FAO 2022), and a prohibition on fishing queen conch at depths greater than 30 m (Morris 2012). These regulations are intended to conserve nursery and breeding areas as well as deep spawning stocks (Morris 2012). There are no minimum size based regulations to prevent harvest of immature conch. There is no closed season for the recreational fishery, but harvesting is limited to three conch per person per day (CITES 2003). Currently, annual quotas for Pedro Bank are determined through a control rule based on harvesting 8 percent of the estimated exploitable biomass (Smikle 2010). Under this scenario, the maximum catch is fixed when densities are above 100 adult conch/ha and are progressively reduced if the population density is reduced. Quotas cannot be increased unless supported by the results of an in-water survey; however, quotas can be lowered if there is evidence of problems, such as a drop in catch per unit effort or a survey indicating a lack of juveniles for future recruitment, and field surveys are mandated at regular intervals. Additional management measures include the designation of the South West Cay Special Fisheries Conservation Area (SWCSFCA) in 2012. Queen conch fishing is prohibited within the SWCSFCA, which extends in a 2-km radius around Bird Key on Pedro Bank. Even so, regulations have not been able to address illegal fishing, which is thought to be problematic based on a spike in catch statistics reported by Honduras and the Dominican Republic during two discrete periods between 2000 and 2002 when Jamaica's fishery on Pedro Bank was closed (CITES 2012). According to the FAO Western Central Atlantic Fishery Commission (2020), a Jamaican national fisheries authority was established, but had an unfunded compliance branch that receives assistance from the Jamaican Coast Guard and Marine Police, though fisheries issues are not a priority. Thus, illegal fishing is thought to remain a serious problem, as further evidenced by the FAO Western Central Atlantic Fishery Commission (2020) observation that "…there is intense IUU fishing by vessels from jurisdictions such as Honduras, Dominican Republic and Nicaragua" within the large Jamaican EEZ.

Effective conservation management measures are particularly important for the Pedro Bank queen conch fishery because it is geographically isolated and receives little gene flow from external areas. Thus, the future of Pedro Bank's queen conch fishery likely depends on local recruitment for sustaining its stocks (Kitson-Walters *et al.* 2018). The health of the Pedro Bank conch population may also be important to species connectivity throughout the Caribbean region, as Jamaica has been identified as an important ecological corridor and a source of larvae to down current jurisdictions (Vaz *et al.* 2022).

In summary, management actions to date have maintained queen conch populations on Pedro Bank, on average, at levels above the necessary threshold required to support successful reproduction (*i.e.,* greater than 100 adult conch/ha); however, existing regulations do not protect immature conch from harvest and may not be adequate to control illegal fishing, prevent habitat degradation, or reverse the decline of queen conch in shallower areas.

Leeward Antilles (Aruba, Curaçao, and Bonaire)

No historical or current fisheries data from the Leeward Antilles islands are available. However, in Bonaire, Lac Bay historically was considered to have been "plentiful in conch." (STINPA 2019, as cited in Patitas 2010). Fisheries were closed in Bonaire and Aruba in 1985 and 1987, respectively, but enforcement of the closure did not begin in Bonaire until the mid-1990s (van Baren 2013). Limited permits, allowing take of adult conch over 18 cm shell length or meat weight over 225 grams (g), were issued in Bonaire through the 1990s. But a moratorium on permit issuance was reported in 2012 due to concern over the extremely low adult population size at that time (van Baren 2013). The limited fisheries-independent monitoring suggests that the island-wide density of conch in Bonaire is very low 21.8 conch/ha. Current densities are too low to support fisheries, despite being closed for more than 30 years in two of the three islands (*i.e.*, Aruba and Bonaire). Queen conch are imported legally from Jamaica and Colombia and illegally from Venezuela to markets in Curaçao and Bonaire (FAO 2007).

The most recent study to assess the status of queen conch in Bonaire was conducted in 2010 in Lac Bay (Patitsas 2010). Within Lac Bay, overall conch density was recorded to be 11.24 conch/ha. The majority of conchs in Lac Bay were adults, constituting 85 percent of the total found (Patitsas 2010). The previous conch density study in Lac Bay was conducted in 1999, and estimated the overall population to be around 22 conch/ha with an average age of 2.5 years (Lott 2001, as cited in Patitsas 2010). Patitsas (2010) concluded the densities in Lac Bay are below the Allee effect threshold of 50 adult conch/ha (Stoner and Culp 2000). No surveys have been done to determine the density and the conditions of the populations in the island of Curaçao (Sanchez, 2017). The only information of the populations in the island of Curaçao located by the SRT is presented in a 2017 thesis on the diet and size of queen conch around the island of Curaçao (Sanchez 2017). While, Sanchez (2017) did not provide conch density data, the author concluded that adult queen conch are very rare surrounding the island, and appear to only occur in restricted places, like the Sea Aquarium Basins, where illegal fishing and predation is limited (Sanchez 2017). The average density of queen conch on the west side of Aruba was 11.3 conch/ha from 2009 to 2011, and the population was dominated by juveniles, suggesting Aruba populations on the west side of the island are not large enough for successful reproduction, though there are isolated areas of higher conch densities (Ho 2011). There is evidence that illegal fishing continues and is further contributing to declines (van Baren 2013; Ho 2011; FAO 2011).

Despite fisheries closures in Bonaire and Aruba since the 1980s, the best available information indicates that there has been limited or no recovery. The most recent available survey, although dated (*i.e.,* more than10 years old) and discussed above, reported very low conch densities and suggest further decline in Lac Bay, Bonaire. There is limited evidence of improvements to management, enforcement, and conservation planning strategies in Aruba, Curaçao, and Bonaire. The lack of recovery in the respective conch populations despite the complete closures of the conch fisheries, indicates that the closures were likely implemented too late because adult conch densities were too low to support reproductive activity. In addition, Aruba, Curacao, and Bonaire appear to have historically relied on larval subsidies of local origin and from Venezuela, and are mostly isolated from other sources of larval supply. Therefore, their ability to recover post overutilization is limited.

Leeward Islands (Anguilla, Antigua and Barbuda, British Virgin Islands, Guadeloupe and Martinique, Montserrat, Saba, St. Barthélemy, St. Martin, St. Eustatius, St. Kitts and Nevis, U.S. Virgin Islands)

Based on the available data, as described in Horn *et al.* (2022), indicates that the majority of the Leeward Islands (*i.e.,* Anguilla, Antigua and Barbuda, British Virgin Islands, Guadeloupe and Martinique, Montserrat, St. Barthélemy, St. Eustatius, St. Martin, St. Kitts and Nevis, and U.S. Virgin Islands) have queen conch populations that are overexploited, with estimated population densities that are below that which is necessary for reproductive success (100 adult conch/ha). The existing regulatory mechanisms largely appear inadequate, resulting in overexploitation and illegal fishing, and have likely contributed to the decline in these populations and reproductive failure. For example, in Anguilla, surveys conducted in 2015 and 2016 found 26 adult conch/ha, which is well below the minimum density threshold for any reproductive activity (50 adult conch/ha) and may not be supporting any reproductive activity (Izioka 2016). Despite low adult densities, fishing for queen conch is still allowed. In addition, existing regulatory mechanisms do not prevent immature queen conch from being harvested. Currently, the minimum landing size for queen conch in Anguilla is 18 cm shell length; however, Wynne *et al.* (2016) found that up to 94 percent of queen conch harvested at that size were immature.

In Antigua and Barbuda, surveys of populations also show low densities and low proportions of adult conch, suggesting that fishing pressure has significantly reduced the adult population to the point where Allee effects are occurring (Ruttenberg *et al.* 2018; Tewfik *et al.* 2001). For example, Tewfik *et al.* (2001) conducted 34 visual surveys (12.84 hectares total) off the southwestern side of Antigua. These surveys recorded 3.7 adult conch/ha, significantly below the 50 adult conch/ha threshold required to support any reproductive activity. Overall conch density (adults and juveniles) for Antigua were 17.2 conch/ha, with juveniles making up about 78.4 percent of the entire population. Reported conch densities in Barbuda are also very low. Ruttenberg *et al.* (2018) reports 29 ± 12 adult conch/ha and 96 ± 30 juvenile conch/ha (mean ± SE). In terms of regulations, both jurisdictions prohibit harvesting of queen conch without a flared lip, or a shell length less than 180 mm, or animals whose meat is less than 225 g without the digestive gland. In addition, Horsford (2019) found over 20 percent of landed conch meat samples were below the minimum legal meat weight in 2018 and 2019, including conch harvested within marine reserves. Evidence of the harvest of undersized and immature queen conch suggests that the existing regulations are either inadequate or are not enforced, or both. Based on the size distribution of queen conch in Barbuda, existing regulations do not necessarily prevent harvesting of immature queen conch. In 2003 the British Virgin Islands implemented regulations that require an 18 cm minimum shell length, a flared lip, a meat weight of at least 226 g, and established a closed season (June 1 through September 30) and prohibited SCUBA gear. However, enforcement of these regulations is questionable as the fishery appears to be essentially unmonitored (Gore and Llewellyn 2005). In addition, as previously discussed shell length and flared shell lip are not reliable indicators of maturity and likely do not prevent immature queen conch from harvest. Given that surveys of queen conch populations in 1993 and 2003 both showed densities of queen conch on the order of less than 0.07 conch/ha, existing regulatory mechanisms may not adequately protect queen conch in the British Virgin Islands from overexploitation (CITES 2003; Ehrhardt and Valle-Esquivel 2008; Gore and Llewellyn 2005).

In Guadeloupe and Martinique, demand is high for local consumption of queen conch (CITES 2003). In 1986, Martinique passed regulations to prohibit the harvest of queen conch with a shell length of less than 22 cm, or shells without a flared lip, or animals whose meat weighs less than 250 g. The majority of landings in Martinique are meat only (FAO 2020), which means that immature queen conch can potentially be harvested as long as the meat weight is greater than 250 g. In Martinique, a closed season runs from January 1through June 30, and the use of SCUBA gear to harvest conch is prohibited. Studies on the reproductive cycle of queen conch in Martinique and Guadeloupe have concluded that the minimum shell length size is not an effective criterion to base sexual maturity (Frenkiel *et al.* 2009; Reynal *et al.* 2009). Thus, the best available information indicates that these regulatory measures are inadequate to prevent the harvest of immature queen conch. Given the increasing demand, with the price of queen conch meat having doubled over the past 25 years (FAO 2020; FAO Western Central Atlantic Fishery Commission 2013), the existing regulations will likely continue to contribute to harvesting of immature queen conch and declines in the queen conch population in the future.

The island of Saba supported large conch fisheries until the mid–1990s. Intensive and unsustainable harvest during the mid-1980s and throughout the 1990s led to the declines on Saba Bank. The Saba Bank was also overfished by several foreign vessels (van Baren 2013). In 1996, fishery legislation prohibited the harvest of queen conch for commercial purposes, and allowed only Saban individuals to harvest queen conch for private use and consumption. These regulations limit Saban individuals to no more than 20 conch per person per year and require that catch be reported to the manager of the Saba Marine Park (van Baren 2013). Nonetheless, collection and reporting laws are not enforced (van Baren 2013). Additional regulations require a 19 cm minimum shell length or a "well-developed lip," and prohibit SCUBA and hookah gears (van Baren 2013). No surveys have been conducted to determine the status of queen conch or if the commercial closure has been effective in rebuilding queen conch stocks (van Baren 2013). Anecdotal evidence indicates that queen conch on the Saba Bank are fished by foreign vessels (FAO Western Central Atlantic Fishery Commission 2013). The island of St. Eustatius had a small commercial conch fishery that exported to St. Maarten. In 2010 the fishery was curtailed because St. Maarten began to require CITES permits for their imports (van Baren 2013).

In the U.S Virgin Islands, the U.S. Federal government has jurisdiction within the U.S. Virgin Island EEZ (*i.e.,* those waters from 3-200 nautical miles (4.8 - 370 km) from the coast) and the CFMC and NMFS are responsible for management measures for U.S. Caribbean federal fisheries. The Government of the U.S. Virgin Islands manages marine resources from the shore out to the 3 nautical miles. At present, the U.S. Virgin Islands manages fisheries resources cooperatively with the CFMC, although not all regulations are consistent across the state-Federal boundary. Recently, the Secretary of Commerce approved three new fishery management plans (FMP) for the fishery resources managed by the CFMC in Federal waters of each of St. Thomas, St. John, and St. Croix. The St.

Thomas and St. John FMP and the St. Croix FMP will transition fisheries management in the respective EEZ from the historical U.S. Caribbean-wide approach to an island-based approach; however, this change does not alter existing regulations for the queen conch fishery. In the U.S. Caribbean EEZ, no person may fish for or possess a queen conch in or from the EEZ, except from November 1 through May 31 in the area east of 64°34' W longitude which includes Lang Bank east of St. Croix, U.S. Virgin Islands (50 CFR 622.491(a)). Fishing for queen conch is allowed in territorial waters of St. Croix, St. Thomas, and St. John from November 1 through May 31, or until the queen conch annual quota is reached. The annual quota is 22.7 mt (50,000 lbs) for St. Croix territorial waters and 22.7 mt (50,000 lbs) for St. Thomas and St. John territorial waters (combined). The CFMC established a comparable annual catch limit (ACL) for harvest of queen conch within the EEZ around St. Croix east of 64°34' W longitude, which includes Lang Bank. When the ACL is reached or projected to be reached across territorial and Federal waters, the Federal queen conch fishery within the EEZ around St. Croix is closed. From 2012 to 2020, commercial fishermen in St. Croix landed between 24 and 74 percent of their ACL; therefore, there were no closures of the queen conch fishery during this time period. In addition to the harvest quotas, commercial trip limits and recreational bag limits for queen conch harvest apply in both territorial waters and Federal waters of the U.S. Virgin Islands. The commercial trip limit in territorial waters and in the U.S. Caribbean EEZ around St. Croix is 200 queen conch per vessel per day (50 CFR 622.495). The recreational bag limit from the EEZ around St. Croix is three per person per day or, if more than four persons are aboard, 12 per vessel per day (50 CFR 622.494). The recreational bag limit in territorial waters is six conch per person per day, not to exceed 24 conch per vessel per day. In the EEZ around St. Croix and in U.S. Virgin Islands territorial waters, regulations require a 22.9 cm minimum shell length or 9.5 mm lip thickness (50 CFR 622.492). In the EEZ around St. Croix and in U.S. Virgin Islands territorial waters, queen conch must be landed alive with meat and shell intact. Finally, Federal regulations at 50 CFR 622.490(a) prohibit the harvest of queen conch in the EEZ around St. Croix by diving while using a device that provides a continuous air supply from the surface.

Surveys of queen conch were conducted in the U.S. Virgin Islands in 2008-2010. The median cross shelf adult density estimate for the three island groups is 44 adult conch/ha, suggesting that densities are too low to support reproductive activity (Horn *et al.* 2022). However, queen conch densities (at all the island groups) were higher in 2008 through 2010 than those observed in the 1980s and 1990s (Boulon 1987; Friedlander 1997; Friedlander *et al.* 1994; Gordon 2002; Wood and Olsen 1983). For example, the mean adult queen conch density estimated for St. Thomas was five times that of adult conch in 2001 (24.2 adult conch/ha) and four times that in 1996 (32.2 adult conch/ha) and ten times that in 1990 (11.8 adult conch/ha) (Gordon 2010). In the 2008-2010 surveys, the population was composed mainly of juveniles (greater than 50 percent) with the remainder of the population spread evenly among the older age classes. Similarly, a more recent survey conducted in Buck Island Reef National Monument (a no-take reserve) estimated 68.5 adult conch/ha and 233.5 juvenile conch/ha (Doerr and Hill, 2018). This age class structure suggests some successful recruitment in this area. However, due to the age of the data from the 2008-2010 surveys, a more recent assessment could better inform stock status. NMFS's 2022 second quarter update to its Report to Congress on the Status of U.S. Fisheries identifies the queen conch stock in the Caribbean as overfished, but not currently undergoing overfishing.

Overall, while queen conch regulations exist within the Leeward Islands to prohibit the harvesting of immature queen conch and manage fisheries, many of these regulations use inadequate proxy measures for maturity, are poorly enforced, and lack effective monitoring controls. For example, minimum shell length, flared lip, and meat weight regulations are unreliable measures to protect immature conch. While lip thickness is a more reliable indicator of maturity for queen conch, values set too low do not ensure that only mature conch are harvested (Doerr and Hill, 2018; Frenkiel *et al.* 2009; Reynal *et al.* 2009; Horsford 2019). The connectivity models (Vaz *et al.* 2022) show a reliance on self-recruitment for the Leeward Islands, with larval transport mainly away from the islands. Thus, queen conch populations throughout the Leeward Islands may continue to decline in the future due to the inadequacy of many of the existing regulatory measures in protecting the Leeward Island conch populations from overutilization and limited larval supply from other locations.

Nicaragua

In Nicaragua, the queen conch fishery was not considered a major fishery until the mid 1990s (CITES 2012). The majority of the queen conch harvest is caught by fishermen targeting lobster, with the remainder made by divers during the lobster closed season (Barnutty Navarro and Salvador Castellon 2013) or incidentally (Escoto García 2004). Landings, quotas, and exports have all increased significantly since the 1990s (Sánchez Baquero 2009). In 2003, Nicaragua implemented regulations that established a 20 cm minimum shell length, a minimal lip thickness of 9.5 mm, a seasonal closure from June 1 through September 30, and set the export quota at 45 mt (Barnutty Navarro and Salvador Castellon 2013; FAO Western Central Atlantic Fishery Commission 2020). Since then, the export quota has increased significantly. In 2009, the export quota was set at 341 mt of clean fillet and 41 mt for research purposes. In 2012, Nicaragua gained additional conch fishing grounds through the resolution of a maritime dispute with Honduras (International Court of Justice 2012), and increased its export quota to 345 mt (Barnutty Navarro and Salvador Castellon 2013; FAO Western Central Atlantic Fishery Commission 2013). By 2019, this quota had almost doubled to an annual export quota of 638 mt (FAO Western Central Atlantic Fishery Commission 2020). The 2020 export quota increased again to 680 mt (see CITES Export Quota). Whether these regulations are adequate to protect the queen conch population from overexploitation is unclear, but a comparison of queen conch densities over the years suggests the current quota may be set too high. For example, results from a 2009 systematic cross-shelf scientific survey conducted by SCUBA divers showed densities ranging from 176-267 adult conch/ha depending on the month (April, July, or November), location, and depth (10-30 m) (Barnutty Navarro and Salvador Castellon 2013). More recent surveys, conducted in October 2016, March 2018, and October 2019, show a decrease in densities to 70-109 conch/ha (FAO Western Central Atlantic Fishery Commission 2020). However, details on these surveys were unavailable and it is unclear if these are adult queen conch densities. Regardless, the available information suggests that overall densities have decreased substantially since 2009, presumably due to the significant increases in the export quota over the past few years. While the densities, if they reflect adult conch densities, may still support some reproductive activity within the queen conch population, the existing regulatory measures, including the current quota, may not be adequate to prevent further queen conch declines in the future. If these trends continue this population is vulnerable to collapse, as the connectivity model (Vaz *et al.* 2022) indicates that Nicaragua's queen conch population is mostly reliant on self-recruitment.

Panama

There is little information available on the status of queen conch or harvest of queen conch in Panama. Georges *et al.* (2010) suggested that the queen conch fishery in Panama may not have specific regulations, but recognized harvest using SCUBA gear is prohibited. In the 1970s, a subsistence fishery was centered in the San Blas Islands (Brownell and Stevely 1981). By the late 1990s, landings data suggest that the queen conch population had collapsed (CITES 2003; Georges *et al.* 2010). In 2000, extremely low adult densities were observed at Bocas del Toro archipelago (approximately 0.2

conch/ha; CITES 2003). The most recent information, although dated, indicates that the fishery was closed for 5 years in 2004 (CITES 2012) and a "permanent closed season" remains in place as of 2019 (FAO 2019). The SAU data suggests that queen conch harvest has continued during the closure with unreported landings likely occurring for subsistence and by the artisan fishery (Pauly *et al.* 2020). In Panama, queen conch appear to be largely self-recruiting (Vaz *et al.* 2022) and more vulnerable to depletion as the population likely does not receive larval recruits from other jurisdictions. The best available information suggests that Panama does not have adequate regulatory measures in place to manage queen conch harvest. While it appears that the harvest is limited to subsistence, the available information suggests that the population has collapsed, and without additional regulations and appropriate conservation planning, it is unlikely that Panama's severely depleted queen conch population will recover.

Puerto Rico

Queen conch populations in Puerto Rico showed signs of steady decline beginning in the 1980s (CITES 2012). Estimated fishing mortality exceeded estimates of natural mortality, catch continued to decline while effort increased through 2011 (CITES 2012), and the catch became increasingly skewed to smaller sizes, all suggesting that Puerto Rican populations have been overfished for decades (Appeldoorn 1993; SEDAR 2007). Surveys conducted in 2013 observed larger size distributions, higher adult queen conch densities (compared to three previous studies, but lower than the density reported in 2006), an increase in the proportion of older adults, and evidence of sustained recruitment, suggesting that Puerto Rico's conch populations are recovering to some extent (Jiménez 2007, Baker *et al.* 2016).

There are several regulations associated with the Queen Conch Resources Fishery Management Plan of Puerto Rico and the U.S. Virgin Islands (CFMC 1996). Recently, the Secretary of Commerce approved new FMPs for the fishery resources managed by the CFMC in Federal waters of U.S. Caribbean. The Puerto Rico FMP will transition fisheries management to an island-based approach.

In 1997, the U.S. Caribbean EEZ (with the exception of St. Croix, U.S. Virgin Islands) was closed to queen conch fishing and a closed season (July 1 through September 30) for territorial waters was implemented. In 2004, additional regulations implemented in local waters included a 22.86 cm minimum shell length or a 9.5 mm minimum lip thickness requirement, daily bag limits of 150 per person and 450 per boat, and a requirement to land queen conch intact in the shell. In 2012, the territorial waters seasonal closure was amended to begin on August 1 and extend until October 31.

In 2013, the Puerto Rico Department of Natural Resources implemented an administrative order that lifted the prohibition on extracting conch meat from the shell while underwater (Puerto Rico Department of Natural and Environmental Resources Administrative Order 2013 -14). The administrative order remains valid today. The elimination of an important accountability mechanism to ensure compliance and enforcement with the minimum size regulations (*i.e.,* the requirement that conch be landed whole), occurred while populations were still considered severely depleted and subjected to continued fishing pressure. Furthermore, shell length is not a reliable indicator of maturity in queen conch. As previously discussed, shell lip thickness is the most reliable indicator of maturity in queen conch; however, the available information indicates that the 9.5 mm lip thickness regulation is not high enough to prevent immature conch from being harvested. Lastly, the mesophotic reef off the west coast of Puerto Rico is likely an important ecological corridor for maintaining connectivity between the Windward Islands and the western Caribbean (Vaz *et al.* 2022; Truelove *et al.* 2017), which means that a decline in queen conch could implicate other jurisdictions down-current. Based on the foregoing, existing regulations are likely inadequate to reverse the decline of queen conch in Puerto Rico.

The Bahamas

Landings data from the 1950s through 2018 have ranged between approximately 750-6,000 mt, with a steadily increasing trend over that period. Prior to 1992, the export of queen conch from The Bahamas was illegal. More recently, at least 51 percent of the landings are exported, with export amounts and values increasing over time, and the bulk of the product exported (99 percent) going to the United States (Posada *et al.* 1997, Gittens and Braynen 2012). The Bahamian government began implementing an export quota system in 1995 and more recently additional protective measures have been implemented including: a SCUBA ban, limited use of compressed air, establishment of a network of marine protected areas, and restricting take to conch with well-formed flared lips (FAO 2007; Gittens and Braynen 2012). The Bahamas also established closed areas, but not closed seasons (Prada *et al.* 2017). Concerns continue regarding IUU fishing, which is likely exacerbating the serial depletion that queen conch are experiencing throughout most of The Bahamas (Stoner *et al.* 2019).

Several fishery-independent studies in both fished and unfished areas within The Bahamas have reported one or more of the following trends since the late 1990s: declines in adult queen conch densities, a reduction in the size of adults on mating grounds, a reduction in the average age of individuals within populations, and a reduction in the number of immature queen conch within nursery grounds (Stoner *et al.* 2019). Recent surveys suggest adult queen conch densities are too low to support any reproductive activity (*i.e.,* <50 adult conch/ha), except in the most remote areas (Stoner *et al.* 2019). Substantial decreases in adult conch densities (up to 74 percent) observed in repeated surveys in three fishing grounds indicate that the conch population is collapsing. In fact, Stoner *et al.* (2019) found that only one location of the 17 locations surveyed in 2011 and 2018, had reproductively-viable adult conch densities. Declines in juvenile populations were reported near Lee Stocking Island where aggregations associated with nursery grounds were estimated to have decreased by more than half between surveys conducted in the early 1990s and 2011 (Stoner *et al.* 2011; Stoner *et al.* 2019). Visual surveys spanning two decades show that densities of adult queen conch had a significant negative relationship with an index of fishing pressure. These surveys also reveal that average shell length in a population was not related to fishing pressure, but that shell lip thickness declined significantly with fishing pressure (Stoner *et al.* 2019). Other less quantitative observations on changing queen conch populations, have been observed over the decades in several nursery grounds (*e.g.,* Vigilant Cay and Bird Cay). While, juvenile aggregations are subject to large inter-annual shifts in conch recruitment (Stoner 2003), these nurseries are typically inhabited by three year classes or more at any one time. However, the near total loss of queen conch at these sites indicates a multi-year recruitment failure or heavy illegal fishing on the nursery grounds (Stoner *et al.* 2019; Stoner *et al.* 2009).

Densities have also declined significantly in three repeated surveys conducted over 22 years in a large no-take fishery reserve (Stoner *et al.* 2019). Unlike fished populations, the protected population has aged and appears to be declining because of lack of recruitment (Stoner *et al.* 2019). Queen conch populations around Andros Island, the Berry Islands, Cape Eleuthera, and Exuma Cays are at or below critical densities for successful reproduction (*i.e.*, >100 adult conch/ha). A fishery closure in the Exuma Cays Land and Sea Park since 1986 has been ineffective in reversing the collapse of the stock in this area (Stoner *et al.* 2019). Some areas of the southern Bahamas, including Cay Sal and Jumentos and Ragged Cays, have maintained queen conch densities greater than 100 adult conch/ha (Souza Jr. and Kough 2020; Stoner *et al.* 2019). However, fishing grounds in the central and northern Bahamas, including the Western and Central Great Bahamian Banks and Little Bahamian Bank, are depleted and regulatory measures are needed to reverse the downward trend (Souza and Kough 2020). Media reports from 2010 through

2020 indicate that remote Bahamian banks are increasingly threatened by illegal fishing as fishers deplete more accessible areas (Souza Jr. and Kough 2020).

The Bahamas is largely self-recruiting, retaining the majority of conch larvae (Vaz *et al.* 2022). The Bahamas does not export a significant amount of larvae to most jurisdictions; however, it does receive a substantial amount of larvae from Turks and Caicos, and to a lesser extent Cuba (Vaz *et al.* 2022). The sustainability of queen conch populations in The Bahamas relies heavily on domestic regulations. Based on the foregoing, the current status and trends of queen conch in The Bahamas indicates that existing regulatory measures in The Bahamas are inadequate to protect queen conch from overutilization and further declines.

Turks and Caicos

The Turks and Caicos one of the largest producers of queen conch meat, providing roughly 35 percent of the total landings reported for the Caribbean region from 1950-2016. In 1994, regulatory measures prohibited the use of SCUBA gear, established annual quotas, set a minimum shell length of no less than 18 cm or a minimum meat weight of no less than 225 g, and stated that all conch landed must have a flared lip. In 2000, a closed season to exports (July 15 through October 15) was established, although queen conch can still be harvested for local consumption during the closed season (DEMA 2012). As previously noted, shell length, flared lip, and meat weight requirements are not reliable indicators of maturity. The existing regulations do not include a minimum lip thickness requirement. It is also notable that queen conch are not required to be landed whole, but the meat may be removed from the shell at sea (Ulman *et al.* 2016), which undermines the effectiveness of most minimum size-based regulations. In addition, while a closed season to exports may decrease demand during the species' reproductive season, it does not fully prohibit the harvest of spawning adult conch.

Two recent studies suggest that the level of exploitation of conch populations in Turks and Caicos may be higher than previously thought. The first study by Ulman *et al.* (2016) performed catch reconstructions that identified a significant problem with underreported fishery landings data from 1950 to 2012. The authors found that the total reconstructed catch was approximately 2.8 times higher than that reported by the Turks and Caicos to the FAO, and 86 percent higher than the export-adjusted national reported baseline. The discrepancies arose because local consumption was not reported and in fact, the total local consumption of queen conch accounted for almost the entire total allowable catch before exported amounts were considered. In response to this study, the catch quota was lowered in 2013.

The last available queen conch survey was completed in 2001. While dated, this survey recorded queen conch densities at 250 adult conch/ha (DEMA 2012). Queen conch harvest is prohibited in the Admiral Cockburn Land and Sea National Park and in the East Harbor Conch and Lobster Reserve. Both protected areas are located in South Caicos (CITES 2012). A study by Schultz and Lockhart (2017) examined the demographics of conch populations inside and outside the East Harbor Conch and Lobster Reserve. The authors identified a lack of algal plain habitat, smaller conch, and lower densities of conch in the reserve. Only one of 118 sites examined inside the reserve contained densities of more than 50 adult conch/ha and none of the sites had densities of more than 100 adult conch/ha. Outside of the reserve, only four of 96 sites had densities of more than 50 adult conch/ha and only one site had a density of more than 100 adult conch/ha. Overall, the densities inside and outside the reserve were similar and had declined by at least an order of magnitude since 2000. The authors cite a lack of habitat inside the reserve and continued fishing pressure within the reserve due to low enforcement presence, as the most likely reasons for an underperformance of the reserve for queen conch conservation.

The Turks and Caicos likely supplies larvae to The Bahamas, and is unlikely to receive larvae from overfished populations up current, and is largely self-recruiting (Vaz *et al.* 2022). Thus, local reproduction is critical for sustaining queen conch in Turks and Caicos. The Turks and Caicos has been one of the largest producers of queen conch meat for decades; however, recent density trends suggest that existing regulations may be inadequate to sustain viable populations.

United States (Florida)

Within the continental United States, queen conch only occur in Florida, where the historical queen conch harvest supported both commercial and recreational fisheries. Regulatory measures were put in place in the 1970s, 1980s, and 1990s (Florida Administrative Code, 1971, 1985, 1990) to first limit and then prohibit commercial and recreational take of queen conch in order to reverse the downward trend of queen conch populations in Florida (Florida Department of State 2021; Glazer and Berg Jr. 1994). The 1990 regulations also provided a stricter framework for shell possession. Habitat loss resulting from coastal developmental contributed to the decline of queen conch populations during the 1980s, and since that time, multiple state and Federal regulations (*e.g.,* Florida Department of Environmental Planning and the Florida Keys National Marine Sanctuary) have limited discharge, development, and other anthropogenic activities that may influence water quality and degrade coastal habitat.

Queen conch are grouped into three "subpopulations" within the Florida Keys based on their spatial distribution (*i.e.,* nearshore, back-reef, and deep-water) (Glazer and Delgado 2020). To date, none of the above measures have been effective in restoring subpopulations in the nearshore, shallow water, and hard bottom habitats immediately adjacent to the Florida Keys island chain. In fact, three populations known to exist in the 1990s remain locally extinct despite 35 years of fishery closure (Glazer and Delgado 2020). Most queen conch in the nearshore areas are not capable of reproduction, which in part, may be due to deficiencies in their gonadal development (Glazer *et al.* 2008; Spade *et al.* 2010; Delgado *et al.* 2019), and very low densities. While the reason for reproductive failure in the nearshore areas has not been clearly identified, contaminants may also play a role in the reproductive failure. In addition, low adult densities, high water temperatures, and natural geographic barriers to movement (*e.g.,* Hawks Channel) appear to limit opportunities for the formation of spawning aggregations that could restore viable populations in nearshore areas. Therefore, it is likely that these populations will continue to decline without additional intervention, despite the protective measures that have been in place for 50 years.

The Florida Keys' back-reef subpopulation is located in shallow water reef flats in habitats primarily consisting of coral rubble, sand, and seagrass (Glazer and Kidney 2004), and has been the focus of fishery-independent surveys since 1993 (Delgado and Glazer 2020). These surveys confirm that the adult abundance of queen conch on back reefs in the Florida Keys has been increasing slowly but steadily since 2007. By 2013, with a few setbacks due to major hurricanes in 2004 and 2005, adult abundance reached approximately 65,000 individuals (Glazer and Delgado 2020). Delgado and Glazer (2020) have confirmed that adult spawning densities in the back-reef are high enough (exceeding 100 adult conch/ha) to support successful reproduction, although the authors never observed mating when aggregation density was less than 204 adult conch/ha, and spawning was not observed when densities were less 90 adult conch/ha.

In summary, queen conch in Florida have experienced large declines since the 1970s due to fisheries harvest and habitat degradation, despite protective regulations being put in place in the 1970s, 1980s, and 1990s. The best available data indicate that the density of large adults is still too low and compromised (*i.e.,* non-reproductive adults in nearshore areas) to restore healthy subpopulations in the Florida Keys: nearshore, back reef, and deep-water. The median adult queen conch density in Florida is less than 50 conch/ha, which is too low for successful reproduction to be maintained throughout the region and for Florida to have a healthy self-recruiting population. Evidence of increasing abundance on back reefs and the restoration of the reproductive capacity of nearshore adult conch following translocation is promising. Fishery closures and other regulatory measures implemented up until the early 2000s may be partially responsible for some of the positive trends that have been observed within the last decade. Recent restoration measures through translocation implemented by the State suggest that queen conch populations may have the capacity to recover with sustained human intervention. Additional regulatory measures outside of Florida are unlikely to have a positive impact on queen conch occurring within Florida because connectivity modeling (Vaz *et al.* 2022) and genetic analysis (Truelove *et al.* 2017) suggest that Florida is largely a self-recruiting population. The commercial and recreational fishery closures in Florida are likely adequate to prevent further overutilization, but, given the longevity of the closures and lack of recovery observed, particularly in nearshore, additional restoration measures are likely needed.

Venezuela

The commercial conch fishery in Venezuela occurred almost exclusively in the insular region, with the archipelagos of La Orchila, Los Roques, Los Testigos, and Las Aves all having significant conch densities (Schweizer and Posada 2006). Until the mid 1980s queen conch were predominantly harvested in Los Roques Archipelago. Studies of the queen conch population around Los Roques Archipelago in the 1980s (Guevara *et al*. 1985) showed the population to be severely overfished, and subsequently the Los Roques Archipelago conch fishery was closed in 1985. Despite the closure, high landings continued (*e.g.*, 360 mt in 1988) and in 1991, the entire commercial queen conch fishery closed (CITES 2003). Most recently, the FAO reported the following annual landings data at 2 mt, in 2016, 2017, and 2018 (see S2 in Horn *et al.* 2022). This illegal harvest of queen conch despite the closure, as well as illegal fishing by other jurisdictions, is thought to be the cause of the low densities and lack of recovery of the Venezuelan queen conch population (CITES 2003). Connectivity models show Venezuela is largely self-recruiting (Vaz *et al.* 2022); thus, queen conch in Venezuelan waters must maintain relatively high adult densities to support recruitment and population growth. Therefore, without adequate enforcement of current regulations prohibiting the harvest of the local queen conch population, which are already depleted and unlikely to be successfully reproducing, densities will likely continue to decline into the future.

Western Caribbean (Mexico, Belize, Honduras)

The jurisdictions in the western Caribbean have a history of industrial-scale exploitation of queen conch. In Mexico and Belize, the queen conch fisheries grew rapidly during the 1970s, which was followed by subsequent declines in queen conch population and densities (CFMC and CFRAMP 1999). In Mexico, the government responded to these declines by implementing temporary and permanent fishery closures in various areas in the 1990s (CITES 2012). Despite these closures and the more recent implementation of size limits, closed seasons, and quotas, Mexico's queen conch population has largely failed (CITES 2012). Density surveys conducted in 2009 show a population that is unlikely to be reproductively viable (De Jesús-Navarrete and Valencia-Hernández 2013). While Mexico reported in 2018 that there have been no legal exports of wild queen conch from Mexico during the previous 7 years (CITES 2018), the FAO data show queen conch exports from Mexico increasing from 204 mt in 2003 to 623 mt in 2018 (see S2 in Horn *et al.* 2022). Given that harvest and export of the already depleted queen conch population in Mexico is still occurring, existing regulatory measures are inadequate to protect the species from overutilization and further decline. Additionally, illegal fishing of queen conch at both the Chinchorro and the Cozumel Banks and at Alacranes Reef is thought to be a significant factor inhibiting recovery (CITES 2012).

In Belize, the heavy exploitation of queen conch almost led to a stock collapse in 1996 (CITES 2003). In response, the government prohibited the selling of diced conch (Government of Belize 2013), instituted minimum shell length (178 mm) and clean meat weight requirements (85 g) to prevent the harvest of immature conch, prohibited harvest by SCUBA gear, and established a TAC limit based on biennial surveys (Gongora *et al.* 2020). While the biennial surveys to determine TAC show relative stability in queen conch size classes over several years, there is evidence of potential overutilization. For example, Foley and Takahashi (2017) found that only 50 percent of female conch were mature at 199 g (clean market meat), which is significantly higher than the current minimum 85 g weight requirement, indicating that this requirement is too low to protect immature conch. In addition, Tewfik *et al.* (2019) documented a significant 15-year decline in the mean shell length of adult and sub-adult queen conch at Glover's Atoll, likely due to the selective harvest of conch with a certain shell length size. This decline in the size distribution may impact productivity because smaller adults tend to have lower mating frequencies and smaller gonads (Tewfik *et al.* 2019), thereby leading to a decline in overall reproductive output.

Tewfik *et al.* (2019) found evidence that indicates Belize's minimum shell length size (178 mm) and market clean meat (85 g) regulations are inadequate to protect juveniles from harvest. Tewfik *et al.* (2019) also found a significant amount of immature conch with shell length sizes over 178 mm and suggest lip thickness should be used as a proxy for maturity, rather than shell length. Based on surveys of queen conch at Glover's Atoll, Tewfik *et al.* (2019) calculated a threshold for the size at 50 percent maturity to be a 10 mm thick shell lip and an associated 192 g market clean meat. However, in Belize, queen conch are not required to be landed intact with the shell. Because most conch meat is removed at sea and the shell discarded, it is the minimum shell size regulations are difficult to enforce and meat weight requirements have diminished value in protecting undersized conch from harvest. Based on the preceding, existing regulations are likely inadequate to protect immature queen conch from harvest and may lead to a decline in recruitment and growth in the future. In fact, the fishing of immature queen conch has been confirmed directly by fishermen and fishery managers, who note that imposing a lip thickness requirement would significantly affect their landings as "the majority of conch that is fished are juveniles" (Arzu 2019; FAO Western Central Atlantic Fishery Commission 2020). In addition, a study conducted by Huitric (2005) presented a historical review of conch fisheries and sequential exploitation. The overall objective of this study was to analyze how Belize's conch fisheries have developed and responded to changes in resource abundance. Huitric (2005) suggests that the use of new technology over time and space (by increasing the area of the fishing grounds), together with fossil fuel dependence and fuel cost, have sustained yields at the expense of depleted stocks, preventing learning about resource and ecosystem dynamics, and removing incentives to change fishing behavior and regulation.

Belize has established a network of marine reserves along the Belize Barrier Reef and two offshore atolls that are divided up into zones of varying levels of protection; however, enforcement of protected areas is limited. For example, long-term declines of reproductively active adult conch have been reported within the Port Honduras Marine Reserve (PHMR) in southern Belize, a no-take zone for queen conch. In fact, densities of conch have been continuously declining since 2009, falling below 88 conch/ha by 2013, and decreasing further to less than 56 conch/ha in 2014 (Foley 2016, unpublished cited in Foley and Takahashi 2017). There have also been reports of illegal fishing near Belize's border with Guatemala as well as reports of Honduras fishermen illegally selling seafood products from Belize (Arzu 2019). In 2017, the Belize Fisheries Department reported confiscating around 4.1 mt of queen conch meat that was harvested out of season (San Pedro Sun 2018). The existing regulations appear adequate to maintain a conch fishery in the short-term because there at least some large mature conch that are protected from fishing located below the depths usually accessed by free-diving (Tewfik *et al.* 2019; Singh-Renton *et al.* 2006). But the existing regulations will likely be inadequate to prevent overutilization of the species in the future, in light of the evidence of significant harvesting of immature queen conch, the decreasing size of adult queen conch in the population, ongoing reports of IUU fishing, and lack of enforcement. Further, Tewfik *et al.* (2019) found that the deep water sites (*i.e.,* fore-reef sites at Glovers Atoll), which are generally protected from fishing due to their location, displayed the lowest overall density (14-4 conch/ha) and were dominated by significantly older individuals (lip thickness >20 mm) that have lower fecundity.

Honduras is one of the largest producers of queen conch meat, with some population monitoring and evidence of general compliance with existing regulations; however, there is also substantial evidence of IUU fishing. In 1996, visual surveys resulted in an overall juvenile and adult density of 14.6 conch/ha (Tewfik *et al.* 1998b). These low densities were attributed to intensive exploitation that had taken place over the previous decades (CITES 2012). However, the most recent survey available conducted in 2011 reported overall conch densities that should be able to sustain successful reproductive activity at two of the three major banks: 134 conch/ha at Roselind; 196 conch/ha at Oneida; and 93 conch/ha at Gorda Banks (Regalado 2012). However, no age structure data was provided with this survey, and therefore the SRT was unable to determine what proportion of the population surveyed are adult queen conch. However, the densities increased with depth, which is most likely the result of fishing effort focused in shallow areas (Regalado 2012). In the early 2000s, there was also evidence that a significant portion of the queen conch meat landed in and exported from Honduras was fished illegally from neighboring jurisdictions. In particular, concerns were raised about a period when Jamaica's fishery at Pedro Bank was closed (2000-

2002), which led to an increase in illegal fishing by foreign vessels (including Honduran vessels) and coincided with an increase in queen conch meat exports from Honduras (CITES 2003; CITES 2012). From 1999 to 2001, Honduras almost doubled its queen conch production, elevating concerns about IUU fishing (FAO 2016). Honduras, in addition to other jurisdictions, was also implicated in unlawful queen conch exports that were confiscated in 2008 during the Operation Shell Game investigation (U.S. House, Committee on Natural Resources, 2008). Illegal fishing has been connected to illegal drug trafficking, increasing the complexity of the issue for fisheries managers and the enforcement challenges (FAO 2016; *canadianbusiness.com*, Illegal trade: raiders of the lost conch, April 28, 2008).

Due to the high amount of exports, lack of landings records, evidence of illegal activity, and low population densities, Honduras was placed under a CITES trade suspension in 2003, and the Honduran government declared a moratorium on conch fishing from 2003 to 2006. From 2006 to 2012, export quotas were set annually for queen conch meat that was taken during scientific surveys (CITES 2012; Regalado 2012). However, based on surveys in 2009-2011 at the three main queen conch fishing banks (Regalado 2012), the mean queen conch landings from 2010 through 2018 represented about 12.3 percent of the standing stock, or more than 50 percent above the recommendation to fish at 8 percent of standing stock, indicating that quotas are being set too high to sustain fishing of these queen conch populations (Horn *et al.* 2022). In 2012, Honduras lost a substantial portion of its conch fishing grounds to Nicaragua in a marine dispute resolution (Grossman 2013). Subsequent to that determination, Honduras terminated its queen conch research program and temporarily ceased generating scientific reports to inform the annual quota allocation.

In 2017, Honduras developed and adopted a formal fishery management plan aimed at establishing legal and technical regulations contributing to the sustainable use of its queen conch populations. Regulations implemented in the plan established a quota of 310 mt of 100 percent clean conch meat to be distributed among 11 industrial fishing vessels. In 2018 and 2019, the total quota increased to 416 mt and was allocated among 13 vessels. Each vessel must carry a satellite monitoring and tracking system during operations and carry one inspector onboard. Minimum size limits were also established at 210 mm shell length, 18 mm shell lip thickness, and a minimum meat weight of 125 g. As previously noted, minimum shell length and meat weight regulations are unreliable since large juveniles can have larger shells and more meat than mature adults. The minimum shell lip thickness of 18 mm likely prohibits immature queen conch from harvest. However, shells are commonly discarded at sea, as the existing regulations do not require queen conch to be landed with the shell intact, which makes it difficult to ensure compliance and enforcement of most size-based regulations. The most recent data (for 2018-2019) show that approximately 416 mt of clean conch meat was landed (Ortiz-Lobo 2019). However, 0.6 mt of conch meat was seized by the Honduran Navy from an unauthorized vessel in November 2018 (Ortiz-Lobo 2019), indicating IUU fishing is still a problem. In addition, fishermen, who agreed to conduct population abundance and density surveys as part of a condition to fish for queen conch under CITES, reversed their decision (Ortiz-Lobo 2019), and abundance surveys from which harvest quotas are established have not been conducted since 2011. The evidence of IUU fishing and the failure to conduct required stock surveys, while increasing export quotas, suggests the existing regulatory measures, including the current allowable quota, are likely inadequate to prevent further declines of the Honduran population of queen conch in the future.

Windward Islands (Barbados, Dominica, Grenada, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago)

In the Windward Islands, queen conch populations appear to be following the same trend as the Leeward Islands, likely due to Allee effects and lack of self-recruitment. Connectivity models (Vaz *et al.* 2022) demonstrate that queen conch in the southern Windward Islands (*i.e.,* Barbados, Grenada, and Trinidad and Tobago) are mostly self-recruiting with larvae hatching and being retained locally; however, it is likely that little to no recruitment is occurring due to the relatively low adult queen conch densities observed throughout the Windward Islands. These low conch densities appear to be the result of overexploitation through sustained and unregulated or inadequately regulated queen conch fishing over the last several decades.

In Barbados and Trinidad and Tobago, there is no management of the queen conch fishery or regulations pertaining specifically to queen conch harvests or sales. While there are no queen conch surveys or assessment for Trinidad and Tobago, declines in abundance were noted as early as the 1970s and 1980s (Georges *et al.* 2010; van Bochove *et al.* 2009; Luckhust and Marshalleck 2004; Lovelace 2002; Brownell and Stevely 1981; Percharde 1968). In a 2010 technical report, 71 percent of fishers interviewed reported declines in queen conch abundance (Georges *et al.* 2010). Queen conch have been overfished and considered depleted in Trinidad and Tobago since the 1990s (CITES 2012). In Barbados, the queen conch catch is mainly comprised of immature individuals, with an estimate as high as 96 percent (Oxenford and Willoughby 2013), indicating highly unsustainable fishing of queen conch. While there is limited information available on queen conch in Dominica, the Significant Trade Review undertaken in 1995 resulted in a CITES suspension of exports from Dominica (Theile 2001).

Grenada has been under a CITES trade suspension since May 2006 due to failure to implement Article IV of the Convention, which requires that the scientific authority of the state has advised that exports will not be detrimental to the survival of the species (a determination known as a 'non-detriment finding'). During this trade suspension, Grenada has continued to export conch to Trinidad and Tobago, and Martinique (exporting 249 mt from 2007-2018; see S2 in Horn *et al.* 2022). However, Grenada recently indicated that it would be working towards a regional action plan for queen conch in an effort to overcome the CITES trade suspension (Blue BioTrade Opportunities in the Caribbean, March 22-23, 2021).

St. Vincent and the Grenadines have regulations in place intended to ensure sustainable conch fishing (FAO 2016). However, regulations have not been updated since they were established in 1987 (Isaacs 2014), and queen conch density has continued to decline since the late 1970s, with estimates of 73 to 78 percent declines, depending on depth area, from 2013 to 2016 (Rodriguez and Fanning 2018). Overall, adult conch density estimates (10.4 conch/ha) are well below the minimum adult density required to support any reproductive activity. Divers have begun using SCUBA gear to reach deep waters as populations have become depleted (CITES 2012). Current regulations prohibit the harvest of queen conch with a shell length less than 18 cm, or without a flared lip, or animals whose total meat weighs less than 225 g. Seasonal closures have not been established and divers fish conch year round (Rodriguez and Fanning 2018; CITES 2012). An export quota was established, based on one of the highest export years recorded in 2002; however, there appears to be no scientific basis for the establishment of the export quota (CITES 2012). In fact, the high level of exports that occurred in 2002 and 2004, was stated to be "influenced by market forces rather than stock abundance" (Management Authority of St. Vincent and the Grenadines *in litt*. to CITES Secretariat, 2004, as cited in CITES 2012). The best available information indicates that existing regulatory measures are inadequate to protect spawning adults, as there is no seasonal closure, and deep water locations are being fished with SCUBA gear. The existing regulations do not include a minimum lip thickness requirement, a more reliable indicator of maturity, to prevent harvest of immature conch and protect spawning. Furthermore, because the existing quota system does not appear to be based on population assessments or surveys, effective monitoring of the fishery is lacking, which has likely contributed to the continued depletion of the queen conch population.

In St. Lucia, the Department of Fisheries implemented regulations in 1996 that prohibit the harvest of queen conch with a shell length less than 18 cm, or without a flared lip, or animals whose total meat weighs less than 280 g without digestive gland (Hubert-Medar and Peter 2012). Conch are harvested in St. Lucia mainly with SCUBA gear. There are no lip thickness regulations to prohibit the harvest of juveniles, and as previously described, shell length and flared lip are not reliable indicators for maturity in conch. In addition, although the Department of Fisheries requires queen conch to be landed whole in the shell, it appears the majority of conch meat is extracted at sea and the shell discarded (Williams-Peter 2021), making the shell length, flared lip and meat weight requirements ineffective mechanisms for protecting the fishery. Queen conch are also fished year round; thus, fishing of spawning adults during their reproductive season is likely occurring (Williams-Peter 2021). Information on stocks is still scarce, especially information on density, abundance, and distribution (Williams-Peter 2021). However, CPUE and landings data (1996-2007) shows that stock have been in a steady decline (Williams-Peter, 2021; Hubert-Medar and Peter 2012) indicating inadequate regulatory controls.

The best available information suggests that most jurisdictions within the Windward Islands use inadequate proxy measures (*i.e.,* shell length, flared lip, and meat weight) to indicate maturity, allowing for immature conch to be harvested. In addition, there is a general lack monitoring of these fisheries to form the basis for their fishing quotas, poor enforcement, and evidence IUU fishing. The connectivity model (Vaz *et al.* 2022) indicates a strong reliance on self-recruitment for these jurisdictions (although there is some exchange within islands), with many of these jurisdictions acting as sources rather than sinks for queen conch larva. Thus, it is likely that queen conch throughout the

Windward Islands will continue to decline due to overutilization and the inadequacy of the existing regulatory measures to address this threat.

Summary of Findings

Given the ongoing demand for queen conch, the lack of compliance with and enforcement of existing regulatory measures, size-based regulations that do not effectively protect juveniles from harvest, and continued illegal fishing and international trade of the species, combined with the observed low densities and declining trends in most of the queen conch populations, the best available scientific and commercial information indicates that existing regulatory mechanisms are generally inadequate to control the threat of harvest and overutilization of queen conch throughout its range. Our review of minimum meat weight, shell length, and flared lip regulations indicates that immature queen conch are being legally harvested in 20 jurisdictions, which is partially responsible for observed low densities and declining populations. Shell lip thickness is considered the most effective criterion for preventing the legal harvest of immature queen conch (Appeldoorn 1994; Clerveaux *et al.* 2005; Cala *et al.* 2013; Stoner *et al.* 2012; Foley and Takahashi 2017), while flared shell lip and minimum shell length requirements do not guarantee sexual maturity. Furthermore, there is general agreement among fisheries managers that no individuals should be harvested before they have had the opportunity to reproduce during at least one season (Stoner *et al.* 2012). Thus, the intent of the minimum size regulations is to protect individuals until they have had the chance to reproduce at least once, assuming that this will return a sustainable supply of new recruits into the population. Nevertheless, only six jurisdictions (*i.e.,* Colombia, Puerto Rico, Nicaragua, U.S. Virgin Islands, Cuba, and Honduras) have minimum shell lip thickness regulations, but only Honduras has a minimum shell lip thickness of at least 18 mm, which is likely the most effective criteria for prohibiting the harvest of immature conch; the other five jurisdictions require a minimum lip thickness that may not ensure maturity (*i.e.*, 5 mm, Colombia; 9.5 mm, Puerto Rico; 9.5 mm, Nicaragua; and 10 mm, Cuba). While historical studies report that some queen conch mature with relatively thin lips (less than 7 mm) (Egan 1985, Appeldoorn 1988), more recent studies indicate that maturation occurs later, at larger sizes, and differs by gender (Doerr and Hill 2018). Several more recent studies indicate that shell lip thickness values at maturity for queen conch range from 17.5 to 26.2 mm for females, and 13 to 24 mm for males (Avila-Poveda and Barqueiro-Cardenas 2006; Aldana-Aranda and Frenkiel 2007; Bissada 2011; Stoner *et al.* 2012). These studies have advocated for increases in the minimum shell lip thickness for legal harvest. Avila-Poveda & Baqueiro-Cárdenas (2006) suggests a minimum up to 13.5 mm by and Stoner *et al.* (2012) suggests 15 mm. While, we recognize that the relationships between shell lip thickness, age, and maturity vary geographically, the best available information demonstrates that the value established for minimum shell lip thickness by most jurisdictions is inadequate to prevent immature conch from being harvested. In addition, the majority of queen conch fisheries (except St. Lucia and the U.S. Virgin Islands) do not have requirements to land queen conch in the shell. Queen conch meat is typically removed and shell is discarded at sea, which undermines enforcement and compliance with regulations for a minimum shell length, shell lip thickness, and flared shell lip. Furthermore, most jurisdictions require a minimum meat weights (125 g to 280 g); however, meat weight is more applicable to catch data, and generally does not constitute a reliable indicator of queen conch maturity (FAO 2017). In addition, 15 jurisdictions do not have regulations that include a seasonal closure, which is essential to prevent the harvest of spawning adults. Similarly, 21 jurisdictions do not have regulations that prohibit the use of SCUBA gear, which could aid in protecting putative deep-water populations. Only a fraction of the jurisdictions (*i.e.,* Belize, The Bahamas, Jamaica, Nicaragua, and Colombia) that have conch fisheries are conducting periodic surveys to gather relevant information on the status of their queen conch populations to inform their national management (*e.g.,* TACs). Available landings data indicate that substantial commercial harvest has led to declines in many queen conch populations to the point where reproductive activity and recruitment has been significantly impacted, particularly throughout the eastern, southern, and northern Caribbean region. Furthermore, several jurisdictions (*e.g.* Curacao and Trinidad and Tobago) have no regulations despite having queen conch fisheries (see S1 in Horn *et al*. 2022). Finally, Aruba (closed 1987), Bermuda (closed 1978), Costa Rica (closed 1989), Florida (closed 1975), Panama (closed 2004), and Venezuela (closed 2000) have completely closed their respective queen conch fisheries. We conclude that fishery closures are likely adequate, if enforced, to prevent further overutilization. However, based on the longevity of the closures, and the lack of recovery observed in each population, it is likely additional measures will be necessary to restore those queen conch populations.

In summation, in some jurisdictions, regulatory controls are non-existent. In other jurisdictions, fishery management regulations aimed at controlling commercial harvest have fallen short of their goals, largely due to a lack of population surveys, assessments, and monitoring, and a reliance on minimum size-based regulations that likely do not prevent the harvest of immature conch or protect spawning stocks. In addition, poor enforcement and compliance with existing regulations combined with significant IUU fishing has greatly reduced the effectiveness of existing regulations. Based on the above, we conclude that the best available information demonstrates that the existing regulatory mechanisms throughout the range of the species are inadequate to achieve their purpose of protecting the queen conch from unsustainable harvest and continued populations decline.

Other Natural and Manmade Factors Affecting its Continued Existence

Direct Impacts to Queen Conch from Climate Change

Queen conch reproduction is dependent on water temperature (Aladana Aranda *et al.* 2014; Randall 1964), and therefore alteration to water temperature regimes may limit the window for successful reproduction. An increase in mean sea-surface temperatures may have direct effects on the timing and length of the reproductive season for queen conch and ultimately decrease reproductive output during peak spawning periods (Appeldoorn *et al.* 2011; Randall 1964). Queen conch reproduction begins at around 26-27^{o}C. Aldana-Aranda and Manzano (2017) observed that nearly all reproduction ceased when temperatures reached 31°C. Early life history stages of queen conch are particularly sensitive to ocean temperature (Brierley and Kingsford 2009; Byrne *et al.* 2011; Harley *et al.* 2006), and rising water temperatures may have a direct impact on larval and egg development (Aldana-Aranda and Manzano 2017; Chávez Villegas *et al.* 2017; Boettcher *et al.* 2003). Aldana-Aranda and Manzano (2017) tested the influence of climate change on queen conch, larval development, growth, survival rate, and calcification by exposing egg masses and larvae to increased temperatures (28, 28.5, 29, 29.5 and 30^{o}C, for 30 days. Queen conch egg masses exposed to water temperatures greater than 30°C resulted in the highest larval growth rate, but also higher larval mortality (76 percent; Aldana-Aranda and Manzano 2017). This study found no link between elevated water temperatures and the calcification process in queen conch larvae. Furthermore, heat stress can induce premature metamorphosis of queen conch leading to developmental abnormalities and lower survival (Boettcher *et al.* 2003). Higher temperatures also accelerate growth rates and decrease the amount of time queen conch spend in vulnerable early stages. For example, faster growth of juvenile queen conch offers earlier protection from predators and shortens the time to reach sexual maturity. While growth may be optimized at higher temperatures up to a certain point, the evidence to date suggests that warming ocean conditions will also lead to higher queen conch mortality rates for early life stages and possible disruption of the shell biomineralization process (Aldana-Aranda and Manzano 2017; Chávez Villegas *et al.* 2017). In addition, other studies have indicated that queen conch veligers developed normally at 28°C, decrease growth at 24°C and have 100 percent mortality at 32°C (Glazer pers. comm, as cited in Davis 2000; Aldana Aranda *et al.* 1989; Aldana Aranda and Torrentera 1987.). However, Davis (2000) found that a temperature of 32°C provided conditions for fast growth and high survival of veligers, but also noted this temperature is probably near the upper physiological tolerance for these veligers. These findings suggest that future water temperatures in the Caribbean Sea are likely to impact survival rates of queen conch during its early life stages.

Climate change will also adversely impact the Caribbean region through ocean acidification, which affects the calcification process of organisms with calcareous structures, like the shells of queen conch. Ocean acidification impedes calcareous shell formation, and thereby impacts shell development (Aldana-Aranda and Manzano 2017; Parker *et al.* 2013). Many mollusks, like queen conch, deposit shells made from calcium carbonate ($CaCO_3$; in the form of aragonite and high-magnesium calcite) and these shells play a vital role in protection from predators, parasites, and unfavorable environmental conditions. Low pH is known to have a strong negative impact on larval development in mollusks, like queen conch, and the very thin shells of queen conch veligers may be especially vulnerable (Chavez-Villegas *et al.* 2017).

The absorption of CO_2 into the surface ocean has led to a global decline in mean pH levels of more than 0.1 units compared with pre-industrial levels (Raven *et al.* 2005, Parker *et al.* 2013). A further 0.3 to 0.4 unit decline is expected over this century as the partial pressure of CO_2 (pCO_2) reaches 800 ppm (Raven *et al.* 2005; Feely *et al.* 2004). At the same time there will be a reduction in the concentration of carbonate ions (CO_3^{-2}), which will lower the $CaCO_3$ saturation state in seawater, making it less available to organisms that use $CaCO_3$ for shells development (Cooley *et al.* 2009; as cited in Parker *et al.* 2013). Ocean acidification impacts to larval queen conch could have major impacts on recruitment to the adult age class, including reproductive populations, throughout the species' distribution (Stoner *et al.* 2021). Whether the impacts of ocean acidification persist over multiple generations and at large enough spatial scales to affect the long-term viability of queen conch populations remains uncertain (Aldana-Aranda and Manzano 2017; Gazeau *et al.* 2013). While changes to ocean pH will likely upset the shell biomineralization processes, and challenge metabolic processes and energetic partitioning, acidic ocean conditions can be patchy in space and time and may develop slowly (Aldana-Aranda and Manzano 2017). Research conducted by Aldana-Aranda and Manzano (2017) observed that acidification conditions produced a 50 percent decrease in aragonite in queen conch larval shell calcification at pH 7.6 and 31^{o}C (see Figure 21 in Horn *et al.* 2022). As previously mentioned, aragonite and high-magnesium calcite are the primary ingredients in queen conch shell formation. Uncertainty with regard to the queen conch's ability to adapt to predicted changing climate conditions, the potential costs of those adaptations, and the projections of future carbon dioxide emissions make it difficult to assess the severity and magnitude of this threat to the species. Recent studies and reviews have stressed the importance of conducting multi-stressor (*e.g.,* elevated water temperature and ocean acidity), multi-generational, and multi-predicted scenario experiments using animals from different areas in order to better understand the impacts of climate change on mollusks at species-wide levels (Aldana-Aranda and Manzano 2017; Parker *et al.* 2013).

Indirect Impacts to Queen Conch from Climate Change

Queen conch nursery habitat includes shallow and sheltered back reef areas that contain moderate amounts of seagrass. These areas are characterized by strong tidal currents and frequent exchange of clear seawater (Stoner *et al.* 1996). Sea level rise, erosion, sea surface temperatures, eutrophication, turbidity, siltation, and severity of hurricanes and tropical storms resulting from climate change can have both short- and long-term impacts on the water quality and health of seagrass meadows (Boman *et al.* 2019; Cullen-Unsworth *et al.* 2014; Grech *et al.* 2012; Burkholder *et al.* 2007; Orth *et al.* 2006; Duarte 2002; Short and Neckles 1999). Depending on the frequency, severity, and scale of climate change-induced conditions, seagrass meadow biomass may decrease at local and over larger scales, reducing conch larvae encounter rates with appropriate queen conch veliger settlement cues (*i.e., Thalassia testudinum* detritus and associated epiphytes; Davis and Stoner 1994). In addition, high water temperatures (greater than 30°C) in the shallow flats where queen conch nurseries occur can result in low oxygen concentrations, which would reduce queen conch growth and may lead to maturation at smaller than normal length, thereby impacting reproductive output (Stoner *et al.* 2021). Juvenile queen conch may experience lower growth and higher mortality rates if they have limited access to adequate food sources and shelter from predators, which are also provided by seagrass meadow communities (Appeldoorn and Baker 2013). Deposits of fine sediment or sediment with high organic content in a wider variety of habitats that adults depend upon (*e.g.,* algal plains, coarse sand, coral rubble, and seagrass meadows) could smother the algae queen conch graze on, thus limiting the nutritional value, and making these habitats unsuitable (Appeldoorn and Baker 2013).

Queen conch are described as stenohaline (Stoner 2003), meaning they tolerate a narrow range of salinities (approximately 34–36 ppt). The species' ability to adapt to short- or long-term intrusions of lower salinity water is uncertain; however, in at least one groundwater-fed coastal area on the Yucatan Peninsula, queen conch movement and growth was not different from core habitat areas with more stable salinity and temperature signatures (Dujon *et al.* 2019; Stieglitz *et al.* 2020). Hypoxic or anoxic conditions may also affect the movement of juvenile queen conch (Dujon *et al.* 2019), which could make them more vulnerable to predation. Changing climate may have subtler effects that could impact tidal flow, circulation patterns, the frequency and intensity of storm events, and larger scale current patterns (Franco *et al.* 2020; van Gennip *et al.* 2017). Changes in tidal flow and current patterns could alter the rate and condition of larval dispersal and the cycle of source and sink dynamics of queen conch populations throughout the Caribbean region. Changes in circulation patterns within the Caribbean Sea would have significant implications for the species.

Summary of Findings

The most significant impacts to queen conch resulting from climate change are increased ocean temperature, ocean acidification, and possible changes in Caribbean circulation patterns. According to several studies, previously discussed, an increase in CO_2 expected by the year 2100 is likely to negatively impact shell formation, since water conditions will be more acidic and potentially dissolve the shells of many mollusks. These studies have also suggested that decreases in aragonite and larval shell calcification occur at a pH 7.6 -7.7, which is projected to occur by 2100 under the very high greenhouse gas emissions scenario (SSP5-8.5; IPCC 2021). These changes in water parameters are likely to result in significantly weaker and thinner shells, which may increase predation rates, thereby contributing to another source of mortality for the species in the foreseeable future. Similarly, changes to other water parameters (*e.g.,* salinity and dissolved oxygen) outside the range of those typically experienced by queen conch can impact their growth and survival and have negative consequences on the seagrass habitat upon which they depend.

The most recent Intergovernmental Panel on Climate Change (IPCC) projections indicate that mean sea surface temperature will warm by 3.55°C by 2100, with the increase in sea surface temperature ranging from 2.45°C to 4.85°C. The available information indicates that the Caribbean Sea will follow the global mean temperature (IPCC 2021; Figure SPM.5). The temperature of the Caribbean Sea has warmed to approximately 28°C at present (Bove *et al.* 2022). Thus, based on the IPCC projections for mean sea surface temperature, it appears that water temperature may increase by approximately 3.55°C suggesting that Caribbean Sea surface temperatures will exceed 31°C under scenario SSP5-8.5 by 2100 (IPCC 2021). A mean sea surface temperature in the Caribbean Sea in excess of 31°C may have negative implications for early life stages and queen conch reproduction. The impacts of acidification on conch larvae could also have significant impacts on recruitment to the adult class, including reproductive populations, throughout the species' range. In addition, possible changes in Caribbean Sea circulation patterns would have significant implications for queen conch recruitment processes and reproduction, but the extent of the impacts from changes in circulation patterns to queen conch is not well understood. Even so, the information is alarming as it indicates that the reproduction, growth, and survival of queen conch will likely be impacted by climate change in the future.

Assessment of Extinction Risk

The ESA (section 3) defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range." A threatened species is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532). Implementing regulations in place at the time the status review was completed described the "foreseeable future" as the extending only so far into the future as we can reasonably determine that both the future threats and the species' responses to those threats are likely. These regulations instructed us to describe the foreseeable future on a case-by-case basis, using the best available data and taking into account considerations such as the species' life-history characteristics, threat-projection timeframes, and environmental variability. The regulations also indicated that we need not identify the foreseeable future in terms of a specific period of time. Although these regulations were vacated on July 5, 2022, by the United States District Court for the Northern District of California and are thus no longer in effect, this approach for determining the "foreseeable future" is consistent with NMFS's longstanding interpretation of this term in use prior to the issuance of these regulations in 2019 (see 84 FR 45020, August 27, 2019).

For the assessment of extinction risk for the queen conch, the "foreseeable future" was considered to extend out several decades (approximately 30 years). Given the species' life history (*i.e.,* density dependent reproduction and longevity estimated to be 30 years), it would likely take more than several decades and multiple generations for management actions to be reflected in population status. Similarly, the impact of present threats to the species could be realized in the form of noticeable population declines within this time frame, as demonstrated in the available survey and fisheries data. We also acknowledge that population recovery is likely dependent on when a protective regulatory measure, such as a closure, is implemented and the status of the population at the time of the closure. For example, Florida, Bermuda, and Aruba prohibited all conch harvest in the mid 1980's (more than 35 years ago), yet their respective populations have yet to recover. Other recovery efforts such as those in Cuba and on Colombia's Serrana Bank were started earlier and recoveries occurred over a shorter timeframe. In addition, in order to fully assess the longer-term threats stemming from climate change and their impacts on queen conch, we considered these threats over a time horizon that extended out to 2100, which is the timeframe over which both climate change threats and impacts to queen conch could be reasonably determined, with increasing uncertainty in climate change projections over that time period. Thus, while precise conditions during the year 2100 are not reasonably foreseeable, the general trend in conditions during the period of time from now to 2100 is reasonably foreseeable as a whole, although less so through time.

Demographic Risk Analysis

In determining the extinction risk of a species, it is important to consider not only the current and potential threats impacting the species' status but also the species' demographic status and vulnerability. A demographic risk analysis is an assessment of the manifestation of past threats that have contributed to the species' current status and informs the consideration of the biological response of the species to present and future threats. The SRT's demographic analysis evaluated the viability characteristics and trends available for the queen conch (*i.e.,* growth rate and productivity, abundance, spatial distribution and connectivity, and diversity) to determine the potential risks these demographic factors pose. The SRT considered the demographic risk analysis alongside the Threats Assessment to determine an overall risk of extinction for the queen conch.

Spatial Distribution and Connectivity

The connectivity modeling considered by the SRT (Vaz *et al.* 2022) indicates that Allee effects are affecting queen conch dispersal rates throughout the Caribbean. Compared to the simulation that showed uniform spawning, it is clear that many important connections for queen conch dispersal have been lost over the past 30 years (see Figures 12, 13, in Horn *et al.* 2022). Many of the larval connections between the Leeward Antilles, which include the Windward and Leeward Islands, and a portion of the Greater Antilles are no longer occurring due to the decreased reproduction, and in some cases, reproductive failure of the queen conch populations within those areas. Many of the Leeward Antilles that once served as source populations are no longer able to contribute to recruitment as their densities are likely too low to support reproductive activity. The model simulations show that conch populations in waters of the Dominican Republic, Puerto Rico, Colombia, Jamaica, and Cuba are integral for larval dispersal and important to maintain connectivity throughout the species' range. The loss (or significant reduction in larvae contributions) of critical up-current source populations (*e.g.,* Leeward Antilles) has placed the species at an increased risk of extinction. The Dominican Republic, Puerto Rico, and Colombia all have populations with cross-shelf densities that are below the critical threshold required to support any reproductive activity. Therefore, it is likely that these populations that are important to facilitate connectivity may be lost in the foreseeable future, contributing to an increase in the species' extinction risk by significantly altering natural dispersal rates. Furthermore, the best available information indicates that historically important source populations within many of the Central American reefs (specifically Quitasueno Bank, Serrana Bank, Serranilla Bank) are likely overexploited, as those populations have low adult densities, and are likely experiencing Allee effects. Based on the results from the connectivity model (Vaz *et al.* 2022) and genetic studies (Truelove *et al.* 2017), these Central American reefs appear to be important for facilitating connectivity within the Caribbean region. In addition, the connectivity model indicates that the eastern Caribbean historically functioned as a source of larvae (and genetic exchange) for the western Caribbean. However, presently, it appears that only the mesophotic population in Puerto Rico is maintaining this connection and is currently at densities that put this recruitment and genetic exchange at significant risk (Vaz *et al.* 2022). Populations in Cuba, Jamaica's Pedro Bank, Nicaragua, Turks and Caicos, and The Bahamas' Cay Sal Bank and Jumentos and Ragged Cays all appear to have queen conch populations that achieve some level of reproductive activity, but they also appear to be largely self-recruiting, offering limited larval dispersal to neighboring jurisdictions, and subsequently providing limited genetic exchange (Vaz *et al.* 2022). While the connectivity model (Vaz *et al.* 2022) suggests that genetic exchange still occurs between populations within the central and southwestern Caribbean, the continued overutilization and inadequacy of existing regulatory measures are likely to reduce queen conch connectivity, placing the species at increased risk of extinction in the foreseeable future. The SRT recognized that there is uncertainty associated with connectivity model because it uses some density estimates that are dated or in some cases, estimates based on unknown survey methodology, though they were the only surveys available (Horn *et al*. 2022). Thus, the SRT assumed that some level of reduced reproduction might continue in areas the connectivity model found to have no larval production.

Overall, depensatory processes are likely limiting queen conch reproduction throughout the species' range. The loss of reproductively viable queen conch populations appears to have likely occurred in most areas throughout the Caribbean. The subsequent reduced larval production has likely resulted in the loss of connectivity among many queen conch populations, further contributing to declines in those populations dependent on source larvae. Thus, based on the best available information, the loss of population connectivity throughout the species' range is likely significantly contributing to the species extinction risk currently and in the foreseeable future.

Growth Rate/Productivity

As discussed previously, queen conch require an absolute minimum density for successful reproduction (see *Spawning Density* section). However, many queen conch populations are presently below the densities required to support any reproductive activity due to low adult queen conch encounter rates. Based on the available data, it is likely that recruitment failure is occurring throughout the species' range. Continued declines in abundance and evidence of overfishing suggests that population growth rates are below the rate of replacement. Of the 39 jurisdictions reviewed, 64 percent (25 jurisdictions), consisting of approximately 27 percent of the estimated habitat available, are below the minimum density threshold required to support any reproductive activity (<50 adult conch/ha). Twenty-three percent (9 jurisdictions), consisting of approximately 61 percent of estimated habitat, are above the 100 adult conch/ha threshold required to support successful reproductive activity. The remaining 13 percent (4 jurisdictions), consisting of approximately 5.5 percent of estimated habitat, had populations with densities that ranged between 50 to 100 adult conch/ha and are likely experiencing reduced reproductive activity resulting in minimal population growth. In other words, queen conch population growth rates in the majority of jurisdictions are likely below replacement levels given their lower densities, and thus, are at increased risk for negative impacts due to depensatory processes. There is also evidence that artificial selection is occurring in some jurisdictions (*e.g.*, Belize and The Bahamas) with fishing pressure leading to the development of smaller adult queen conch. Smaller adult queen conch are thought to be less productive (*e.g.,* lower mating frequencies, smaller gonads, and fewer eggs) than larger queen conch. Thus, queen conch populations that are showing evidence of overfishing, and decreasing adult size will likely result in declines in abundance and lower densities, further contributing to declines in those populations in the foreseeable future. Several SRT members also noted that queen conch could likely withstand moderate harvest levels, as the species is very productive when at sufficient densities and may have the ability to compensate. However, given the extremely high levels of harvest occurring throughout the species' range, including high levels of illegal fishing, harvesting of juveniles, and evidence of significant population declines throughout most of the Caribbean, the majority of SRT members concluded, and we agree, that current population growth and productivity rates are contributing to the species extinction risk currently and in the foreseeable future.

Abundance

There are no region-wide population estimates for queen conch. To assess the species abundance, the SRT considered numerous sources of information including abundance estimates, stock assessments, surveys, landings and trends, habitat availability, and other biological indicators. Total population abundance estimates ranged from 451 million to 1.49 billion individuals, based on the 10th and 90th percentile abundance estimated across jurisdictions. These estimates, however, required numerous assumptions, in particular the assumed extent of conch habitat. In addition, for many areas, available survey data were limited, outdated (may have been collected decades ago), or unavailable. In addition, many density estimates were also unavailable or unable to be calculated because the survey methods and data collected were poorly described (*e.g.,* unknown whether an abundance reported adult conch or juvenile and adult conch). These data limitations and analytical assumptions contribute to high uncertainty in the SRT's abundance estimates.

Considering these limitations, the best available data suggest queen conch populations are experiencing Allee effects, with densities that are consistently very low and insufficient to support reproductive activity and mate finding. While several populations of queen conch appear to remain reproductively active based on the available survey data, these populations are limited to St. Lucia, Saba, Jamaica's Pedro Bank, Cuba, Turks and Caicos, Nicaragua, Costa Rica, The Bahamas' Cay Sal Bank and Jumentos and Ragged Cay, and Colombia's Serrana Bank, and the population surveys for some of these locations are outdated or unavailable (see Table 2; Figure 7 in Horn *et al.* 2022). In addition, some of the exploitation rates are significantly above the recommended maximum harvest rate of 8 percent of the standing stock for population densities capable of supporting successful reproduction (*i.e.,* >100 adult conch/ha). The SRT found that of the 9 jurisdictions that have populations above the 100 adult conch/ha threshold, four are experiencing exploitation rates that exceed the 8 percent target: Jamaica (8.7 percent exploitation rate), Nicaragua (8.8 percent exploitation rate), St. Lucia (16 percent exploitation rate), and Turks and Caicos (30 percent exploitation rate). Overall, of the 39 jurisdictions reviewed, approximately 20 jurisdictions (51 percent) had exploitation rates significantly above the recommended maximum 8 percent harvest for healthy populations (see S4 in Horn *et al.* 2022), despite a lack of evidence that those populations are capable of supporting successful reproductive activity.

Moreover, significant harvest levels and regulatory enforcement issues (*e.g.,* illegal fishing and harvest of juveniles) will continue to negatively impact population growth and recruitment, thereby decreasing abundances and potentially leading to extirpations in the foreseeable future. Any local disturbances (natural or anthropogenic), or environmental catastrophes (*e.g.,* hurricanes) that affect those jurisdictions in the future could result in population declines that would have extensive negative implications for the species overall given the depensatory issues occurring throughout the Caribbean region.

The SRT's extrapolated abundances are based on density estimates and habitat estimates. The SRT made efforts to quantify the uncertainty inherent in basing the abundance estimates on survey data reported using different methodologies, over a wide time span, and range of spatial scales. The majority of the SRT concluded that low and declining abundances and densities significantly increases the species' extinction risk currently and over the foreseeable future. Members of the SRT acknowledged that Cuba, The Bahamas' Cay Sal Bank and Jumentos and Ragged Cay, Turks and Caicos, Jamaica's Pedro Bank, and Nicaragua likely have populations with higher abundance and densities that indicate successful reproductive activity is occurring. However, approximately 25 jurisdictions (64 percent) have very low densities (<50 adult conch/ha) that are insufficient to support any reproductive activity or population growth. While another 5 jurisdictions (13 percent) have adult queen conch population densities between 50 and 100 conch/ha and are likely experiencing reduced reproductive activity, resulting in minimum population growth. Only 9 jurisdictions (23 percent) have adult queen conch densities at or greater than 100 conch/ha, which is required for successful reproduction and recruitment (UNEP 2012). Thus, the best available information on abundance reveals that declines throughout the species' range is likely significantly contributing to the species extinction risk currently and in the foreseeable future.

Diversity

As discussed above, early genetic studies of queen conch found a high degree of gene flow among populations dispersed over the species' geographic distribution, with definitive separation observed only between populations in Bermuda and those in the Caribbean basin (Mitton *et al.* 1989). More recent studies have found low genetic differentiation among locations in the Mexican Caribbean, the Florida Keys and Bimini (Pérez-Enriquez *et al.* 2011; Zamora-Bustillos *et al.* 2011; Campton *et al.* 1992). Mitton *et al.* (1989) hypothesized that the complex ocean currents of the Caribbean may restrict gene flow among Caribbean populations, even though larvae may disperse long distances throughout the Caribbean during their 16-28 day pelagic larval duration. Truelove *et al.* (2017) identified significant levels of genetic differentiation among Caribbean sub regions (*e.g.,* Florida Keys, Mesoamerican Barrier Reef, Lesser Antilles, Honduras, Jamaica, Greater Antilles, and The Bahamas) and between the eastern and western Caribbean regions (Truelove *et al.* 2017).

The connectivity model (Vaz *et al.* 2022) indicates there are several important jurisdictions that act as ecological corridors in facilitating population connectivity in the Caribbean region. For example, loss of Puerto Rico mesophotic populations would likely result in the loss of the genetic connectivity between the southeastern and western Caribbean. Furthermore, the connectivity model and literature suggest that the Nicaraguan rise, which includes the territorial seas of Honduras, Nicaragua, Colombia, and Jamaica, is likely to be an important region for maintaining population connectivity over larger spatial scales. These findings are consistent with those observed in Truelove *et al.* (2017). Many of these jurisdictions are currently overexploiting their conch populations. However, at this time, the best available information does not suggest that significant changes in or loss of phenotypic or genetic traits are altering genetic diversity to the extent that it is significantly contributing to the species' extinction risk. Therefore, we conclude that diversity is unlikely to be significantly contributing to the species' extinction risk currently or in the foreseeable future.

Threats Assessment

As described above, section 4(a)(1) of the ESA and NMFS's implementing regulations (50 CFR 424.11(c)) state that we must determine whether a species is endangered or threatened because of any one or a combination of the ESA section 4(a)(1)(A)–(E)) factors. We provide here our findings and conclusions regarding threats to the queen conch described previously in this document, and their impact on the overall all extinction risk of the species. More details can be found in the status review report (Horn *et al.* 2022).

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The most significant threat to queen conch is overutilization (through commercial, artisanal, and IUU fishing) for commercial purposes. Fishing for queen conch substantially increased in the 1970s and 1980s, reaching peak landings in the mid 1990s (Horn *et al.* 2022). It was during this time that many of the conch fisheries collapsed due to overfishing of the populations. In shallow waters, where conch are most accessible to both subsistence and commercial fishing, significant depletions have been recorded, with fishermen having to pursue the species into progressively deeper waters. Overfishing has caused population collapses throughout the range of the conch, contributing to known or likely reproductive failure in many locations (*i.e.,* Anguilla, Antigua and Barbuda, Aruba, central and northern Bahamas, Belize, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, portions of Colombia, Dominican Republic, Guadeloupe, Haiti, Martinique, Mexico, Panama, St. Vincent and the Grenadines, Puerto Rico, U.S. Virgin Islands, Unities States (Florida), and Venezuela). Only a handful of jurisdictions in the Caribbean have conch populations with densities high enough to support successful reproduction (*i.e.,* Cuba, Costa Rica, Saba, St. Lucia, Turks and Caicos, Nicaragua, Jamaica's Pedro Banks, Colombia's Serrana Bank, and The Bahamas' Cay Sal Bank and Jumentos and Ragged Cay), with the viability of the species likely dependent on the persistence of those queen conch populations. Historically, the Leeward Islands (*i.e.,* Anguilla, Antigua and Barbuda, British Virgin Islands, Guadeloupe, Montserrat, Saba, St. Barthélemy, St. Martin, St. Eustatius, St. Kitts and Nevis, and U.S. Virgin Islands) and Windward Islands (*i.e.,* Barbados, Dominica, Grenada, Martinique, St. Lucia, St. Vincent and the Grenadines, and Trinidad and Tobago) in the eastern Caribbean likely served as important sources of larvae to the central and western Caribbean (Vaz *et al.* 2022). Although recruitment from undescribed deep-water populations is possible, queen conch populations in the Leeward Islands are unlikely to recover given they are primarily self-recruiting and up-current from most larval sources.

According to the SAU database there are 12 jurisdictions that have produced 95 percent of the conch landings from 1950 through present: Turks and Caicos, The Bahamas, Honduras, Jamaica, Belize, Nicaragua, Dominican Republic, Mexico, Cuba, Antigua and Barbuda, Colombia, and Guadeloupe (in order from highest landings producers to lower producers) (see Figure 17 in Horn *et al.* 2022). The exploitation rate analysis indicates that queen conch populations in The Bahamas, Honduras, Jamaica's Pedro Bank, and Nicaragua are likely exploited very near the targeted 8 percent rate of standing stock to maintain a healthy population. Of the other top-producing jurisdictions in the region, Dominican Republic, Antigua and Barbuda, Belize, Turks and Caicos, and Mexico's landings significantly exceed the 8 percent exploitation rate target (see Figure 18 in Horn *et al.* 2022). For example, the estimated exploitation rate for the Turks and Caicos is 30 percent of the stock, nearly quadruple the recommended rate. These unsustainable fishing rates are of particular concern because many of these jurisdictions (*i.e.,* Dominican Republic, Antigua and Barbuda, Belize, and Mexico) have adult queen conch densities below the minimum levels required to support any reproductive activity. Furthermore, we share the SRT's concerns about incomplete, inadequate and inconsistent data, such as self-reported landings data. Additionally, recreational and subsistence fishing are rarely tracked during data collection efforts, and the collective impacts of these activities, and IUU fishing (discussed below) can at times, be equal to or greater than the pressure from commercial fisheries. Without more accurate population assessments and harvest level estimates, there is a lack of reliable evidence that queen conch populations are fished at sustainable levels.

Illegal, unreported and unregulated (IUU) fishing, in particular, is a threat that is significantly contributing to the species' extinction risk currently and in the foreseeable future, although there is uncertainty regarding the magnitude of this threat. The best estimates of IUU fishing are most likely underestimated and may account for a significant portion (greater than 15 percent) of total catch. IUU fishing of queen conch is a significant problem throughout the range of the species, and particularly within Nicaragua, Honduras, Jamaica, the Dominican Republic, Haiti, and Colombia (see S1 in Horn *et al.* 2022). Illegal, unreported and unregulated fishing has led to declines in queen conch abundance and is thought to have prevented recovery of several populations (*e.g.,* Bonaire, Cayman Islands, and St. Eustatius). In the few jurisdictions with reproductively active queen conch populations (adult densities >100 conch/ha), illegal fishing is a serious threat as these removals are not considered in the management of fishing quotas. Thus, overall harvest levels likely exceed what is sustainable for the species.

The threat posed by IUU fishing on those reproductively active populations (densities >100 adult conch/ha) will likely be exacerbated by decreasing adult densities and reproductive failure (as observed elsewhere) in the long-term. There is no evidence to suggest that IUU fishing will decline in the foreseeable future. In fact, it will likely intensify as queen conch populations become depleted and more queen conch fisheries close.

Based on the aforementioned assessments, we conclude that overutilization is significantly contributing to the species' risk of extinction currently and in the foreseeable future. In general, the best available information indicates that queen conch harvest data are likely underreported due to incomplete and inconsistent data collection as well as IUU fishing. These facts, coupled with evidence of significant population declines that have resulted in Allee effects which limit reproduction and requirement indicate that queen conch are overexploited throughout most of its range and will likely continue to decline in the foreseeable future.

Inadequacy of Existing Regulatory Mechanisms

Queen conch populations have declined throughout a large portion of the species' range, and the best available information indicates that many populations continue to decline, particularly in the eastern and central southern Caribbean. There are still some jurisdictions throughout the species' range that have not implemented any regulatory mechanisms, and of those that have, many regulations are insufficient to prevent further declines in existing conch stocks (*e.g.,* Dominican Republic, Haiti, and Puerto Rico). In general, regulations in most jurisdictions are aimed at prohibiting the take, sale, or possession of immature queen conch and they rely on a minimum shell length, meat weight, shell lip thickness, and flared shell lip criteria or some combination of these. As previously discussed, studies conducted on established maturation criteria have demonstrated that in most jurisdictions the minimum lip thickness value is not set high enough prevent the harvest of immature conch. Similarly, minimum shell length and meat weight criteria are unreliable because large immature queen conch can have larger shells and more meat than adults. In addition, the flared shell lip, which occurs at about 3.5 years of age, is frequently used as a criteria to ensure that immature conch are not harvested. However, the available information indicates that maturity lags substantially behind the formation of the flared shell lip (Cala *et al.* 2013; Stoner et al, 2012b; Clerveaux *et al.* 2005; Appeldoorn, 1994; Appeldoorn 1988; Buckland 1989; Eglan 1985). Therefore, it is unlikely that the flared shell lip criteria is preventing harvest of immature conch in most jurisdictions throughout the species' range. Moreover, St. Lucia and the U.S. Virgin Islands are the only jurisdictions that have regulations requiring queen conch be landed in the shell. No other jurisdictions require queen conch to be landed whole in its shell, which undermines the effectiveness of existing morphometric regulations that cannot be enforced after the shell has been discarded at sea.

The SRT noted that seasonal and area closures can be effective regulatory controls if they are established in appropriate habitats, encompass reproductive seasons, and are effectively enforced. Reproductive seasons vary in timing and duration in different regions of the Caribbean, spanning between 4 to 9 month periods between April and October, but most often between June and September. Many jurisdictions (16) have a closed season for some time during the calendar year with the intent to protect spawning and reproduction. These seasonal closures range from 2 to 6 months and most occur during the months of July, August, and September because these are peak months for reproduction (Stoner *et al.* 2021; Horn *et al*. 2022). This is generally consistent with the recommendation made by Aldana-Aranda *et al*. (2014) that a "biologically meaningful period for a closed season for the entire western central Atlantic would need to incorporate the months of June to September, at a minimum, to offer regional protection for spawners." More recently, Boman *et al*. (2018) recommended a slightly longer region-wide closure from May through September. The only jurisdictions with a closed season extending 5 months are the Cayman Islands, Cuba, and Jamaica. Several jurisdictions begin closed seasons somewhat late *(e.g.*, July), leaving some periods with highest reproductive potential vulnerable to harvest (Stoner *et al*. 2021). In addition, evidence suggests in some cases, closed seasons for queen conch are decided with respect to closure dates for other species. For example, the timing of the Jamaica closed season is not related to peak spawning season but is determined by timing of the lobster season.

SCUBA and hookah gear restrictions provide some auxiliary protection for putative deep water populations, but they are often triggered by diving accidents and causalities in the queen conch fishery. Only a few jurisdictions currently prohibit the use of SCUBA gear in their queen conch fishery. Jurisdictions that establish appropriate regulations are often plagued by poor enforcement and illegal fishing. Queen conch, in particular, tend to be harvested by individual divers, and the large shelf habitats and remote fishing grounds make it is difficult to patrol these areas to enforce conch harvesting regulations. Furthermore, the available jurisdiction-specific information make significant reference to illegal conch fishing, as it is a well-documented problem throughout the Caribbean. Illegal, unreported, and unregulated fishing is acknowledged by most, if not all, regional and international management organizations (CFMC, OPSECA, FAO, CITES, *etc.*).

In light of the ongoing demand for queen conch, the problems identified with the appropriateness of certain morphometric regulations, the challenges associated with compliance and enforcement of regulations (including IUU), combined with the observed low densities and declining trends in most queen conch populations, existing regulatory mechanisms are inadequate to control the harvest and overutilization of queen conch throughout its range. Therefore, based on the best available information, we conclude that the existing regulatory mechanisms are significantly contributing to the species extension risk currently and in the foreseeable future.

Other Natural or Manmade Factors Affecting its Continued Existence

Increasing ocean temperature, ocean acidification, and altered circulation patterns are consequences of climate change, that are likely to impact queen conch. Queen conch reproduction is dependent on temperature, thus changes in water temperature may limit the window for successful reproduction. A recent study found that nearly all queen conch reproduction stopped when temperatures reached 31°C. The temperature of the Caribbean Ocean at present is approximately 28°C (Bove *et al.* 2022). The Intergovernmental Panel on Climate Change projections for mean sea surface temperature indicates that sea surface temperatures are expected to exceed 31°C by 2100 under scenario SSP5-8.5 (IPCC 2021). These findings suggest that future sea temperatures will significantly decrease queen conch reproduction. In addition, larval growth and mortality are also likely to be impacted by the increased sea surface temperatures expected to occur by 2100 (*i.e.,* exceeding 31°C). Laboratory studies showed that increased ocean temperatures resulted in high growth rates for queen conch, but also higher mortality rates (of up to 76 percent). However, it is difficult to predict how queen conch may adapt to these changing environmental conditions and whether higher growth rates would partially offset increased mortality. In addition, the predicted increased acidity associated with oceanic CO_2 uptake will likely impact shell biomineralization processes as well, potentially leading to weaker, thinner shells for queen conch. Recent studies have suggested a 50 percent decrease in aragonite in the larval shell calcification at conditions expected to occur by 2100 (pH 7.6-7.7; IPCC 2021). Weaker shells may increase predation rates, thereby increasing mortality for the species in the foreseeable future. Higher mortality rates will likely have significant implications for conch populations that rely significantly on self-recruitment. In addition, the best available information indicates climate change will likely influence ocean circulation patterns in the Caribbean (van Westen *et al.* 2020; Goni and Johns 2001; Paris *et al.* 2002), which may have substantial consequences for queen conch. While no direct studies have been conducted for queen conch, several studies focusing on reef fish and corals indicate that changes to ocean circulation have the potential to impact marine reef organisms through altered larval dispersal, survival, and population connectivity (Munday *et al.* 2009; Cowen *et al.* 2003). Changes to ocean circulation patterns are also likely to influence larval supply dynamics, pelagic larval stage survival, as well as their condition upon settlement. Information is lacking on how changes in circulation patterns will impact local populations or how it will alter population connectivity on a regional scale. While there is uncertainty surrounding the extent of climate change impacts to the species in the foreseeable future, the best available scientific information indicates that queen conch will likely be impacted by increases in sea surface temperature, ocean acidification, and altered circulation patterns resulting from climate change. Thus, we conclude that the best available information indicates that climate change is significantly contributing to the species extinction risk in the foreseeable future.

Overall Extinction Risk Analysis

Guided by the results from the demographics risk analysis as well as threats assessment, the SRT members used their informed professional judgment to make an overall extinction risk assessment for the queen conch. Here, we first review the SRT's findings and next discuss our conclusions regarding the risk of extinction to queen conch. The SRT used a ‘‘likelihood point” (Forest Ecosystem Management Assessment Team 1993) method to evaluate the overall risk of extinction and express uncertainty. Each SRT member distributed 10 “likelihood points” among three extinction risk categories:

Low risk: A species is at low risk of extinction if it is not at moderate or high level of extinction risk (see “moderate risk” and “high risk” below). A species may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.

Moderate risk: A species is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of "high risk" below). A species may be at moderate risk of extinction due to current and/or projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species is more likely than not to be at high risk in the foreseeable future depends on various case- and species-specific factors.

High risk: A species with a high risk of extinction is at or near a level of abundance, productivity, spatial distribution/connectivity, and/or diversity that places its continued persistence in question. The demographics of a species at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species may be at high risk of extinction if it faces clear and present threats (*e.g.,* confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create imminent and substantial demographic risks.

The SRT placed 59 percent of their likelihood points in the "moderate risk" category. Due to uncertainty, particularly regarding consistent reporting of landings and survey methodologies, the SRT also placed some of their likelihood points in the "low risk" (30 percent) and "high risk" (11 percent) categories. The SRT concluded that the queen conch is currently at a "moderate risk" of extinction. We consider the SRT's approach to assessing the extinction risk for queen conch appropriate, consistent with our agency practice, and based on the best scientific and commercial information available.

One of the most critical factors in the long-term survival of the species is localized densities of reproductively active adults. The results of our analysis revealed that 25 jurisdictions (*i.e.,* Anguilla, Antigua and Barbuda, Aruba, the central and northern Bahamas, Barbados, Belize, Bermuda, Bonaire, British Virgin Islands, Colombia's mainland, Quitasueño, and Serranilla Banks, Curaçao, Dominica, Dominica Republic, Grenada, Guadeloupe, Haiti, Martinique, Mexico, Monserrat, Panama, St. Vincent and the Grenadines, St. Barthelemy, Trinidad and Tobago, United States (Florida), Puerto Rico, U.S. Virgin Islands, and Venezuela) have adult densities below the critical threshold of 50 conch/ha required for any reproductive activity. These jurisdictions equate to approximately 27 percent (19,625 km^2) of the estimated habitat available in the Caribbean region. Another 5 jurisdictions (*i.e.,* Cayman Islands, Honduras, St. Eustatius, St. Kitts and Nevis, and Puerto Rico's mesophotric reef) have adult densities that are below the 100 conch/ha minimum threshold for successful reproductive activity. There are 9 jurisdictions (*i.e.,* Costa Rica, Cuba, Colombia's Serrana Bank, The Bahamas' Cay Sal Bank and Jumentos and Ragged Cays, Jamaica's Pedro Bank, Nicaragua, Saba, St. Lucia, and Turks and Caicos) that have adult conch densities (>100 conch/ha) sufficient to sustain successful reproductive activity. These jurisdictions contain approximately 61 percent (44,589 km^2) of the estimated habitat available in the Caribbean region. Additionally, modeling indicates connectivity has been significantly impacted across the Caribbean region (Vaz *et al.* 2022). A number of historically important ecological corridors for larval flow are no longer functional, and most of the queen conch populations that historically served as sources of larvae have collapsed.

Available density data can be difficult to interpret for several reasons, including because survey methods varied, surveys were lacking from many areas and, in some cases, surveys were decades old. In addition, conch are not distributed evenly across space; even in jurisdictions with very low densities there likely exist some areas above the critical density threshold where some reproduction continues to take place (*e.g.,* Florida). In terms of the extrapolated total abundance estimates, which suggest there are millions of conch in the Caribbean, the SRT noted that this was primarily based on highly uncertain population estimates from 7 jurisdictions (*i.e.,* The Bahamas, Jamaica, Turks and Caicos, Cuba, Nicaragua, Honduras, and Mexico), which account for 95 percent of all adult conch. Furthermore, density is a stronger indicator of a population's status than total abundance, as adult conch density directly influences the probability of locating a receptive mate. If high numbers of queen conch exist, but are widely distributed over a large geographic area, the species' low mobility reduces the likelihood of a reproductive encounter between two adults, thus limiting overall productivity and sustainability of the population. The best available density and abundance information, despite its limitations, suggests that there are localized depletions in most jurisdictions that have led to near-reproductive failure. Therefore, the population growth rate is likely below the rate of replacement and recruitment failure is likely occurring in most populations.

Further declines of queen conch are expected into the foreseeable future as the species remains at risk due to overutilization and the inadequacy of existing regulatory mechanisms. Overfishing has been the main threat to queen conch for several decades, creating patchy, disconnected populations and resulting in low local densities, with little indication that existing regulatory measures are capable of reversing this trend in the Caribbean region, as many regulations use inappropriate morphometric metrics and are poorly enforced. In fact, the combination of overutilization and inadequate regulations has led to the decline of many queen conch populations, particularly those in the eastern and southern parts of the Caribbean, where queen conch populations have become so depleted they can no longer support fisheries and are likely experiencing recruitment failure. The best available information indicates that the viability of the species is currently reliant on the queen conch populations predominantly located in the central and western parts of the Caribbean, specifically those queen conch populations found in Cuba, The Bahamas' Cay Sal Bank and Jumentos and Ragged Cay, Turks and Caicos, Jamaica's Pedro Bank, and Nicaragua. While these jurisdictions likely support reproductive queen conch populations (based on best available adult density estimates), they also operate queen conch fisheries that are unlikely to remain sustainable over the next 30 years, based on the estimated exploitation rates. As these jurisdictions are largely self-recruiting, overfishing of these populations will result in further declines, which will have significant impacts on the reproductive output, and overall viability of the species in the foreseeable future. This is particularly concerning as Jamaica's Pedro Bank is an important ecological corridor that supports larvae exchange throughout the region. Thus, if Jamaica's queen conch population were to become reproductively impaired, it would further reduce population connectivity, creating additional susceptibilities for the remaining conch populations. In addition, IUU fishing contributes to overutilization of the species because there is a lack of adequate regulatory mechanisms and enforcement of the regulatory measures that are in place, particularly in Colombia, Cuba, Dominican Republic, The Bahamas, Honduras, Jamaica, Nicaragua, and Turks and Caicos. Left unchecked, these additional removals will likely accelerate declines in abundance and associated densities over the next 30 years. As conch fisheries continue to close and populations become depleted, IUU will likely continue or increase, and without adequate enforcement to halt illegal harvest of conch, the species will continue to be on a downward trajectory and at risk of extinction over the next 30 years. The implementation and enforcement of appropriate management measures could reduce the threat of overutilization to the queen conch, but existing regulations and, more importantly, the enforcement of these regulations are currently either inadequate or lacking altogether across the species' range.

Finally, threats resulting from climate change include increased sea surface temperature, ocean acidification, and altered circulation patterns. Increased sea surface temperature and ocean acidification may result in decreased reproductive activity and increase veliger mortality rates, further exacerbating impacts to recruitment for this species. Changes in circulation patterns in the Caribbean Sea may represent a significant and widespread threat to queen conch larval dispersal, survival, and recruitment processes, but the extent to which this threat will impact the species survival is not well understood at this time. While there is some uncertainty as to the timing of any shifts that may occur, as well as the spatial scale over which it will occur, we conclude that the best available information indicates climate change will significantly contribute to the species' extinction risk in the foreseeable future.

Based on all of the foregoing information, which represents the best scientific and commercial data available regarding current demographic risks and threats to the species, we conclude that the queen conch is not currently in danger of extinction, but is likely to become so in the foreseeable future throughout all of its range. We conclude that the species does not currently have a high risk of extinction due to the following: the species has a broad distribution and still occurs throughout its geographic range and is not confined or limited to a small geographic area; the species does not appear to have been extirpated from any jurisdiction and can still be found, albeit at low densities in most cases, throughout its geographic range; and there are several jurisdictions that have queen conch populations that are contributing to the viability of the species, such that the species is not at imminent risk of extinction. As previously discussed, there are 9 jurisdictions that are estimated to have adult queen conch densities greater than 100 conch/ha and they comprise of about 61 percent of the estimated queen conch habitat. Note, if The Bahamas was removed from the set of 9 jurisdictions, the habitat estimate would be reduced to 32 percent. Of the 9 jurisdictions, queen conch populations in Cuba, Jamaica, and some of Colombia's banks, have high BC values (see Figure 13 in Horn *et al.* 2022), indicating that these areas facilitate the flow of queen conch larvae, allowing for some exchange of larvae and maintenance of some genetic diversity.

Significant Portion of Its Range

Under the ESA, a species warrants listing if it is in danger of extinction or likely to become so in the foreseeable future throughout all or a significant portion of its range (SPR). In 2014, the United States Fish and Wildlife Service and NMFS finalized a joint Significant Portion of its Range Policy (SPR Policy) that provided an analysis framework and definition for a “significant” portion of a species’ range (79 FR 37577; July 1, 2014). However, several aspects of this joint policy have since been invalidated. Specifically, in *Center for Biological Diversity* v. *Everson*, 435 F. Supp. 3d 69 (D.D.C. 2020), the court vacated the aspect of the 2014 SPR Policy that provided that the Services do not undertake an analysis of significant portions of a species’ range if the species warrants listing as threatened throughout all of its range. In addition, the SPR Policy's definition of “significant” was vacated nationwide in 2018 (See *Desert Survivors* v. *U.S. Dep't of Interior*, 321 F. Supp. 3d 1011 (N.D. Cal. 2018)). Therefore, we now conduct SPR analyses even in cases where we reach a conclusion that a species is threatened range wide, and we conduct species-specific evaluations to determine whether a portion of a species’ range is “significant.” In determining whether a “portion” qualifies as “significant,” we evaluate the biological importance and contribution of the species within the portion to the viability of the overall species using key principles of conservation biology. In particular, we consider the “portion’s” contribution to the viability of the species as a whole in terms of abundance, productivity, connectivity, and diversity from past, present, and future perspectives to the extent possible and depending upon the best available species-specific data and information.

As discussed in the SPR Policy, theoretically, there are an infinite number of ways to divide a species’ range into portions; however, there is no purpose in evaluating portions that do not have a reasonable likelihood of being both “significant” and, in this case, at “high risk” of extinction. Therefore, a screening analysis was conducted to identify appropriate portions of the range for further evaluation. Because there are multiple levels of biological organization by which we could screen portions of the queen conch's range for purposes of this analysis, rather than using any one level or scale, we considered three different spatial scales: (1) the jurisdictional scale, which separately considers the 39 management jurisdictions or "populations" (as described in Vaz *et al.* 2022); (2) the ecoregional scale, which groups one or more 39 management jurisdictions into 10 marine ecoregions (Spaulding *et al.* 2007); and (3) one macroregion (*i.e.,* Lesser Antilles), which groups two of the 10 marine ecoregions into a single portion. As described in further detail in this section, at each of these scales, portions of the species' range were screened to determine whether it is potentially at "high risk" and whether it is potentially "significant." If both screening tests were met, the particular portion was evaluated further to determine whether the queen conch in that portion are facing a high risk of extinction, and if so, whether the portion is "significant."

Management Jurisdictional ("Population") Approach to SPR

The most granular level used in the SPR analysis is the management jurisdiction approach. The SRT felt this approach was appropriate because the resolution of management jurisdiction is consistent with the level of resolution available for the primary threats to the species (*i.e.,* overutilization and inadequacy of regulatory measures) and the available data to inform viability of the species, including landings data, survey data, and connectivity data (Horn *et al.* 2022; Vaz *et al.* 2022). The majority of relevant queen conch data (*i.e.,* connectivity, density, landings, and exploitation rates) were collected or summarized at the jurisdiction level, and the main threats to queen conch are managed at the jurisdiction level. Following Vaz *et al.* (2022), the SRT evaluated "populations" based on jurisdictional boundaries (*i.e.,* populations were defined by jurisdictional divisions). At this level of resolution, the SRT found that it could more accurately evaluate the risk and potential significance of a population.

Dozens of management jurisdictions needed to be evaluated by the SRT and data availability and quality were variable. To streamline the analysis, the SRT first screened for any portions of the range for which there is substantial information in the record indicating both (1) the species is reasonably likely to be at a "high risk" in that portion; and, (2) the portion is reasonably likely to be significant. Areas for which substantial information indicated the jurisdiction met both of these tests qualified for further consideration. To conduct this initial screening step, the SRT developed a standardized assessment tool with specific screening criteria, which provided a consistent frame of reference for determining potential risk level and significance across management jurisdictions (see S4 in Horn *et al.* 2022). The standardized assessment tool focused upon distinguishing characteristics for potential risk as denoted by spawning aggregation density and potential significance as denoted by potential contributions to population viability.

In the assessment tool, a portion of the species' range was potentially at a "high risk" of extinction if the jurisdiction had an exploitation rate of more than 8 percent, or median adult queen conch density less than 50 conch/ha. The assessment tool's decision framework flags jurisdictions exceeding the 8 percent target exploitation rate because this is a region-wide guideline for establishing sustainable queen conch fisheries (*i.e.,* fishing should remove no more than 8 percent of the biomass of a healthy stock; Prada *et al.* 2017). Given that the goal for the 8 percent exploitation rate is "sustainability" of queen conch fisheries that have densities capable of supporting successful reproductive activity (*i.e.,* at least 100 adult conch/ha), flagging jurisdictions exceeding this benchmark is a conservative approach for identifying portions where the species is potentially high risk. The SRT also considered populations with median adult queen conch density below 50 conch/ha as potentially high risk because populations with densities below this threshold are at significant risk of reproductive failure.

In the assessment tool, a jurisdiction was considered potentially significant if it met one of the two criteria (criterion 1 or criterion 2) regarding its contribution to the viability of the species, *and* a third criterion (criterion 3) regarding its connectivity to the other populations:

1. Abundance of queen conch in the jurisdiction is greater than 5 percent of the overall estimated species abundance; or
2. Habitat in the jurisdiction is greater than 5 percent of all available queen conch habitat; and
3. Jurisdiction was historically important to population connectivity, having functioned as an important source population or ecological corridor.

This approach to screening for potentially significant contributions to viability considers both the population's contemporary contributions to species abundance (criteria 1) and the population's historical capacity for carrying a substantial portion of species abundance based on available habitat (criteria 2). Available habitat was used as a proxy for historical population size following Vaz *et al.* (2022) because in many jurisdictions queen conch have been depleted by decades of overfishing and survey data are unavailable to inform unfished population sizes. Although the actual densities of conch spawning biomass that historically may have been supported within a given jurisdiction would be dependent on the particular habitat attributes of that area, comprehensive maps of habitat types across the Caribbean region, as well as information on the relationships between habitat types and their respective conch densities at carrying capacity are not available. In the absence of such detailed information, the SRT assumed that equal spawning biomass densities and consistent per-capita fecundity rate across the region were reasonable approximations for understanding relative historical population sizes and relative overall connectivity patterns in a pre-exploitation historical scenario.

The independent consideration of available habitat (criteria 2) ensured that populations failing to meet criteria 1 due to declines in abundance (*i.e.,* prior overexploitation) could still be considered as potentially significant based on their ability to support conch populations, as inferred from available habitat. Relatively low thresholds (5 percent) were set for criteria 1 and 2 to ensure an inclusive evaluation of any potential portion of the species' range evaluated at the management jurisdictional scale.

The final threshold in the SRT's assessment tool for potential significance (criteria 3) assessed a jurisdiction's ability to make meaningful contributions to the viability of the species as a whole. This criterion was screened using a BC value that was above the median across all jurisdictions (Vaz *et al.* 2022). The BC value measures the relative influence of a jurisdiction's queen conch reproductive output on the flow of larvae among every other pair of jurisdictions in the species' range. The SRT considered the BC from unexploited scenarios across hydrodynamic models simulated in Vaz *et al.* (2022) to assess each jurisdiction's contribution to the viability of the species as a whole. The unexploited BC value represents the historical connections between populations created by larval dispersal and is an indicator of overall potential "connectedness" of individuals within each jurisdiction. The median was selected to delimit high versus low levels of connectivity, as measured by BC. Use of the median as the screening statistic is appropriate given the BC values are a relative scale of non-normally distributed values (Vaz *et al.* 2022). If reproductive output from jurisdictions with high BC (*i.e.,* above the median) were to decline significantly, reduced genetic mixing over the region as a whole would be expected, as was reported by Vaz *et al.* (2022) under contemporary exploitation levels. The SRT used BC values from the unexploited connectivity scenario (Vaz *et al.* 2022), which accounts for historical spawning potential and is not biased by contemporary reductions in reproductive output from overexploited locations. We agree with the SRT that using the pre-exploitation BC measure represents the "potential" of a jurisdiction to contribute to the spatial connectivity of the species as a whole. Jurisdictions with a high BC value historically functioned as ecological corridors and were biologically important to facilitate larval and genetic flows, preventing the fragmentation of the range (Vaz *et al.* 2022). Thus, the BC measure (criteria 3) evaluates each jurisdiction's historic contributions to viability, especially spatial connectivity, regardless of their current status. Additional discussion of the assessment tool and methodological details are provided in see Horn *et al.* (2022).

Results of the Management Jurisdictional ("Population") Approach to SPR

By using this assessment tool, the SRT identified 30 potentially high-risk conch jurisdictions and 3 potentially significant jurisdictions (File S4 in Horn *et al.* 2022). Only the Nicaragua jurisdiction met both the potentially high risk and potentially significant criteria. No other portions of the species range at the jurisdiction level met both the potentially high-risk and potentially significant criteria (File S4 in Horn *et al.* 2022). The SRT concluded, by consensus, that no other portions of the species range at the jurisdiction level warranted further consideration.

The SRT further evaluated the Nicaragua portion of the species' range to determine whether this jurisdiction was both significant and at a "high risk" of extinction. Because both of these conditions must be met, regardless of which question is addressed first, if a negative answer is reached with respect to the first question addressed, the other question does not need to be evaluated for that portion of the species' range. In undertaking the SPR analysis for queen conch, the SRT elected to address the "high risk" of extinction question first. The members of the species within the portion may be at "high risk" of extinction if the members are at or near a level of abundance, productivity, spatial structure, or diversity that places the members' continued persistence in question. Similarly, the members of the species' within the portion may be at "high risk" of extinction if the members face clear and present threats (*e.g.,* confinement to a small geographic area; imminent destruction, modification, or curtailment of habitat; or disease epidemic) that are likely to create imminent and substantial demographic risks.

As with queen conch throughout its range, the most significant threat to Nicaragua's portion of the population is overutilization through commercial, artisanal, and IUU fishing. Nicaragua is one of the primary producers of queen conch meat in the Caribbean, and its landings and fishing quotas have increased substantially since the mid 1990s. For example, in 2003, Nicaragua set its quota at 45 mt (processed meat), but in 2009, the quota had increased to 341 mt (processed meat) and 41 mt quota for scientific purposes (bringing the total queen conch quota to approximately 382 mt). By 2019, the scientific quota was revoked and the processed meat quota almost doubled to an annual export quota of 628 mt (FAO Western Central Atlantic Fishery Commission 2020). The most recent density estimates, conducted in 2016, 2017, and 2018 indicate that densities are sufficient to support some recruitment; however, comparisons between survey years suggest a declining trend. For example, surveys conducted in 2009 recorded approximately 176–267 conch/ha, while surveys conducted in October 2016, March 2018, and October 2019 indicated 70-109 conch/ha suggesting a decline in densities (FAO Western Central Atlantic Fishery Commission 2020). No additional information was provided on the methodology for the more recent surveys (*i.e.,* no location, season, area, or age class were provided).

Depensatory issues are a major factor limiting the recovery of overharvested queen conch populations (Appeldoorn 1995; Stoner *et al.* 2012c). In addition, queen conch within the Nicaraguan portion of the species' range are likely heavily reliant on self-recruitment (Vaz *et al.* 2022), which means that local depletions would have negative implications on its ability to recover. Based on the available information, the SRT concluded that the decreasing trend in queen conch densities within this jurisdiction, coupled with increasing quotas suggests inadequate management of the conch fishery and a likelihood of unsustainable fishing of the stock.

The SRT noted that the current estimated exploitation rate in Nicaragua (*i.e.,* 8.8 percent) was only slightly above the 8 percent target for sustainable fishing for stocks with a density of at least 100 adult conch/ha. The best available information suggests that the current exploitation levels exceed sustainable levels for the level of reproductive activity in Nicaragua. Considering the current exploitation rate (and potential for increases in this rate, given the trend in the quota-setting over the years), and the declining trend in queen conch densities, the SRT concluded that the best available information indicates that this subpopulation is not currently at a "high risk" of extinction. We have reviewed the SRT's assessment, definitions, and rationale, and agree with its determination. Thus, we conclude that the Nicaraguan portion of the species' range is not currently in danger of extinction, but is likely to become so within the foreseeable future. This finding is consistent with the species' range wide determination, that queen conch is not currently in danger of extinction, but is likely to become so within the foreseeable future.

Ecoregional Approach to SPR

We, NMFS, broadened the SRT's SPR evaluation, and considered whether there were additional portions or combinations of portions that might be both significant and at "high risk." We extended the SRT's approach of evaluating populations at the jurisdictional scale to evaluating metapopulations at the broader ecoregional scale. We evaluated ten recognized marine ecoregions within the Caribbean Basin, Gulf of Mexico and the southwest Sargasso Sea (8–35 °N, 56–98 °W) as queen conch population portions: (1) the Northern Gulf of Mexico, (2) the Southern Gulf of Mexico, (3) the Floridian, (4) Bermuda, (5) the Bahamian, (6) the Greater Antilles, (7) the Southwestern Caribbean, (8) the Western Caribbean, (9) the Eastern Caribbean, and (10) the Southern

Caribbean (see Figure 1in Spalding *et al.* 2007). These marine ecoregions represent broad-scale patterns of species and communities in the ocean, and were designed as a tool for planning conservation across a range of scales and assessing conservation efforts and gaps worldwide. These marine ecoregions also closely track the connectivity analysis of Vaz *et al.* (2022), as the broad-scale patterns of species and communities used to designate ecoregions reflect spatial proximity and hydrodynamic connectivity. Using defined marine ecoregions enabled us to use a globally recognized approach to group management jurisdictions into larger population portions for the SPR analysis that is consistent with our specific understanding of queen conch population connectivity and regional hydrodynamic processes. As such, the jurisdictions within the ten marine ecoregions are similar in regards to their contributions to the viability of the species.

Of the ten marine ecoregions considered, four (*i.e.,* Northern Gulf of Mexico, Southern Gulf of Mexico, Floridian, Bermuda) consist of single jurisdictions (*i.e.,* Mexico, parts of which make up the Northern and Southern Gulf of Mexico ecoregions, Florida and Bermuda) and were evaluated by the SRT under the *Management Jurisdictional ("Population")* approach described above. None of those single jurisdictions met both the potentially high risk and potentially significant criteria used by the SRT to warrant further evaluation.

NMFS evaluated the other six marine ecoregions (*i.e.,* the Bahamian, the Greater Antilles, the Southwestern Caribbean, the Western Caribbean, the Eastern Caribbean, and the Southern Caribbean) to determine whether any could be identified as potentially significant portions of the range. There are limited differences in terms of adequacy of existing regulations or management measures across the species' range. In addition, the main threat to the species (overutilization) is widespread throughout the species' range. However, several portions of the species' range may be facing greater demographic risks. As such, following the SRT's screening approach described above, we focused our analysis on the percentage of jurisdictions within an ecoregion with likely reproductive failure (*i.e.,* <50 adults/ha) to determine if an ecoregion was potentially "high risk." An ecoregion was determined to be potentially at "high risk" if the majority of jurisdictions within the portion were below the 50 adults/ha threshold.

To determine if an ecoregion was "potentially significant," we evaluated contributions to population viability based on habitat availability and connectivity similar to criterion 2 and 3 above, but at a larger spatial scale. The percentage of available conch habitat across all jurisdictions within an ecoregion was easily aggregated. We used the available habitat within an ecoregion relative to the total habitat within the species' range as a metric for the ecoregion's potential historical contribution to population viability. The data for connectivity could not be aggregated across jurisdictions within an ecoregion; therefore, we focused on the percentage of jurisdictions within the ecoregion that were highly connected, as denoted by the historical BC values above the median. Highly connected jurisdictions within the ecoregion serve (or once served) as important larval sources, facilitating gene flow and maintaining population connectivity. We considered an ecoregion to be potentially "significant" if the percentage of queen conch habitat within the ecoregion exceeded 5 percent of the total available conch habitat across the range (criteria 2 from above) and the majority of jurisdictions within the ecoregion were highly connected as indicated by a high historical BC value (criteria 3 from above). This approach allows us to evaluate the ecoregions historical capacity for carrying a substantial portion of the species abundance and its ability to make meaningful contributions to the viability of the species as a whole in determining whether the ecoregion is significant.

Results of the Marine Ecoregional Approach to SPR

1. The Bahamian

The Bahamian ecoregion consists of The Bahamas and the Turks and Caicos. The waters of these two countries represent 30 percent of the available queen conch habitat and contain an estimated 118 million spawning adult queen conch with densities exceeding 100 conch/ha. Neither of these jurisdictions has median adult density estimate below 50 conch/ha; thus, this ecoregion does not meet the threshold to be considered potentially at “high risk.” As such, we did not evaluate whether this ecoregion might be significant.

2. The Greater Antilles

The Greater Antilles ecoregion consists of the British Virgin Islands, Cuba, the Cayman Islands, Dominican Republic, Haiti, Jamaica, Puerto Rico, and the U.S. Virgin Islands. Half of the jurisdictions in the Greater Antilles portion have median adult densities estimates below 50 conch/ha; however, an estimated 473 million spawning adults remain in jurisdictions with adult queen conch densities greater than 100 conch/ha. Thus, this portion does not meet the threshold to be considered potentially at “high risk.” As such, we did not evaluate whether this ecoregion might be “significant.” We did note that the eight jurisdictions in the Greater Antilles ecoregion represents 36 percent of the total estimated queen conch habitat and 63 percent of the jurisdictions within this ecoregion are highly connected.

3. The Southwestern Caribbean

The Southwestern Caribbean ecoregion consists of Colombia (mainland and offshore banks), Costa Rica, Nicaragua, and Panama. Together, these 4 jurisdictions represent 10 percent of the total available queen conch habitat, and 75 percent of these jurisdictions were highly connected. Only Panama had adult queen conch densities below 50 conch/ha. Within the Southwestern Caribbean ecoregional portion, an estimated 89 million spawning adults remain at adult densities greater than 100 conch/ha. Thus, this ecoregion does not meet the threshold to be considered potentially at "high risk." As such, we did not evaluate whether this ecoregion might be "significant."

4. The Western Caribbean

The Western Caribbean ecoregion consists of Belize; Honduras; Guatemala; and Quintana Roo, Mexico. Of these jurisdictions, Guatemala was not evaluated due to lack of data. The jurisdictions in the Western Caribbean ecoregion are characterized by low median densities, inadequacy of existing regulatory mechanisms to prevent juvenile harvest (Horn *et al.* 2022; Arzu 2019, Tewfik *et al.* 2019), and continued illegal harvest (Horn *et al.* 2022; CITES 2012). Of the three jurisdictions with data, two (67 percent) have median adult densities below 50 conch/ha, and none of the three have median adult densities greater than 100 conch/ha. We note, that several surveys in Belize, Honduras, and Mexico have identified locations with queen conch densities greater than 100 conch/ha; however, many of these density estimates included immature conch. There are three surveys in Belize and 18 in Mexico that reported adult queen conch densities greater than 100 conch/ha (Figure 20 in Horn *et al.* 2022); however, most of these surveys were conducted more than a decade ago. We note, that surveys near Xel-Ha in Quintana Roo, Mexico recorded adult queen conch densities between 405 and 665 conch/ha (Aldana Aranda *et al.* 2014); however, these surveys were conducted in 2012 and the study areas was small (1 ha). Thus, because the majority of jurisdictions in the Western Caribbean ecoregion have median adult queen conch densities less than 50 conch/ha, this ecoregion was identified as potentially at "high risk."

Having identified the Western Caribbean ecoregion as potentially at "high risk," we evaluated whether this ecoregion is potentially "significant." The Western Caribbean ecoregion contains 12 percent of the total available conch habitat. Honduras has limited local retention of conch larvae (Vas *et al.* 2022). Historically, Honduras would have supplied larvae to Belize and Mexico. Currently, Honduras acts as mostly a sink for larvae from Nicaragua and Colombia's Serrana Bank. Mexico's conch population has low local larvae retention. With regards to connectivity, Belize mostly acts as a sink and has substantial local retention. Belize receives a significant supply of larvae from Honduras, and to a lesser extent Nicaragua. Historically, Mexico's conch population provided larval to the United States (Florida) and received larvae from upstream sources. Presently, Mexico does not appear to be supporting reproductive activity, but receives larvae from Honduras and Colombia's Serrana Bank, and, to a lesser extent, from Cuba and the Cayman Islands. Because of the position of the Western Caribbean ecoregion, jurisdictions within this ecoregion supply larvae to upstream jurisdictions within the ecoregion and to the Florida ecoregion. More specifically, queen conch larvae from Quintana Roo, Mexico appear to have been an important historical source of larval supply to the Floridian ecoregion, which functions as a sink (Vaz *et al.* 2022). Presently, reproduction is thought to be nominal with no viable upstream sources of larvae suggesting a limited capacity for recovery. Nonetheless, because less than the majority of jurisdictions in the Western Caribbean ecoregion (33 percent) are highly connected; we determined that the Western Caribbean ecoregion is not "significant."

5. The Eastern Caribbean

The Eastern Caribbean ecoregion consists of Anguilla, Antigua and Barbuda, Barbados, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, Saba, Sint-Eustatius, St. Barthelemy, St. Kitts and Nevis, St. Lucia, St. Maarten, and St. Vincent and Grenadines. The majority of jurisdictions within this ecoregion (73 percent) have adult queen conch densities below 50 conch/ha, suggesting this ecoregion is potentially at "high risk." This ecoregion represents just 5 percent of the total estimated queen conch habitat, but 73 percent of the jurisdictions are highly connected, suggesting this ecoregion is potentially "significant."

We further evaluated the Eastern Caribbean ecoregion to determine whether this portion of the species' range is at a "high risk" of extinction. We determined that an estimated 5 million spawning adults remain in jurisdictions (*i.e.,* Saba and St. Lucia) with adult queen conch densities greater than 100 conch/ha. A single female conch lays between 7–14 egg masses containing between 500,000–750,000 eggs during a single spawning season (Appeldoorn 2020). Thus, the approximately 5 million conch (see S5 in Horn *et al.* 2022) in viable spawning aggregations could produce up to 26 trillion eggs in a single spawning season. The Eastern Caribbean ecoregion likely has reasonably high levels of self-recruitment (Figures 5, 6, and 8 in Vaz *et al.* 2022). Given the high reproductive capacity of queen conch presently at viable spawning aggregation densities in this ecoregion and the capacity for self-recruitment within the ecoregion, we determined Eastern Caribbean ecoregion is not currently at "high risk." We did note that in Saba, there is documented illegal fishing of queen conch in marine parks, with no established quotas for queen conch fisheries (van Baren 2013). Additionally, in St. Lucia, there is a declining trend in CPUE and inadequate enforcement of regulations (Williams-Peter 2021). Thus, we conclude that the Eastern Caribbean portion of the species' range is not currently in danger of extinction, but is likely to become so within the foreseeable future, due to the ongoing threats, and the declining trends in abundance and productivity in the majority of the jurisdictions within the Eastern Caribbean portion of its range. This finding is consistent with the species' range wide determination, that queen conch is not currently in danger of extinction, but is likely to become so within the foreseeable future.

6. The Southern Caribbean

The Southern Caribbean ecoregion consists of Aruba, Bonaire, Curacao, Trinidad and Tobago, and Venezuela. These five jurisdictions all have estimated densities less than 50 adults/ha, suggesting this ecoregion is potentially at "high risk." Of the five jurisdiction, three of them (60 percent) are highly connected. However, the Southern

Caribbean ecoregion comprises just 2 percent of the total available queen conch habitat throughout the species' range. As such, this ecoregion's historical ability to contribute to the viability of the queen conch species is limited, and this ecoregion does not meet potentially "significant" threshold for the purposes of our SPR evaluation.

Macroregional Approach to SPR

The Eastern and Southern Caribbean ecoregions, both of which were identified as potentially at "high risk," are located upstream of most major harvesters of queen conch, and have experienced declines or collapses in many regional queen conch fisheries. Given this outcome, to ensure a rigorous analysis, we also considered a broader geographic scale by combining the Eastern and Southern Caribbean ecoregions into the more broadly recognized "Lesser Antilles" macroregion. This macroregion comprises 21 jurisdictions (*i.e.,* Anguilla, Aruba, Antigua and Barbuda, Barbados, Bonaire, Curacao, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, Saba, St. Eustatius, St. Barthelemy, St. Kitts and Nevis, St. Lucia, St. Maarten, St. Vincent and Grenadines, Trinidad and Tobago, and Venezuela). These jurisdictions form the eastern boundary of the Caribbean Sea where it meets the Atlantic Ocean and represent the furthermost upstream source for queen conch larvae in the range.

Based on the marine ecoregional approach described above, we analyzed whether the majority of jurisdictions within the Lesser Antilles macroregion, have adult queen conch densities below the 50 conch/ha threshold indicating that the Lesser Antilles macroregion is potentially at "high risk." Similarly, we analyzed whether the percentage of queen conch habitat within the Lesser Antilles macroregion exceeded 5 percent of the total available habitat (criteria 2 from above), and whether the majority of jurisdictions within the macroregion were highly connected (criteria 3 from above) to determine if the Lesser Antilles macroregion was potentially "significant."

Results of the Macroregional Approach to SPR

Of the 21 jurisdictions within the Lesser Antilles macroregion, 17 (81 percent) have adult queen conch densities below the reproductive threshold of 50 conch/ha, suggesting this macroregion is potentially at “high risk.” We note that the density estimates for 8 of the 21 jurisdictions within the Lesser Antilles macroregion are approximated from nearest neighbors due to the lack of surveys in those jurisdictions; only 10 of 21 jurisdictions (48 percent) have more contemporary jurisdiction-specific adult density estimates that are below 50 conch/ha.

Contemporary abundance of queen conch within the Lesser Antilles macroregion is estimated at 19 million adults, with historical capacity based on habitat availability estimated to comprise up to 8 percent of the unexploited population. For comparison, contemporary estimates suggest at least 725 million reproductive adult conch exist outside the Lesser Antilles portion (Horn *et al.* 2022). Of the 21 jurisdictions within the Lesser Antilles macroregion, 13 (61 percent) are "highly connected" based on BC values above the median. Because we estimate that the Lesser Antilles macroregion contains 8 percent of the available habitat for the species and because the majority of jurisdictions within macroregion are highly connected, the Lesser Antilles macroregion meets the potentially “significant” threshold. We note that the majority (10 of 13) of the “highly connected” jurisdictions within the macroregion have adult queen conch densities below 50 conch/ha. However, we also note that the highly connected jurisdictions within the macroregion with adult densities below 50 conch/ha represent only 3 percent of the total available queen conch habitat throughout the species’ range.

Because we identified the Lesser Antilles macroregion as potentially “high risk” and potentially “significant,” we further evaluated the risk level for this macroregion. The Lesser Antilles macroregion is characterized by a lack of an upstream source of larvae and a high likelihood of reproductive failure in many jurisdictions. Of 21 jurisdictions within the macroregion, only two jurisdictions (Saba and St. Lucia) have median adult queen conch densities greater than 100 conch/ha. However, a single female conch lays between 7–14 egg masses containing between 500,000–750,000 eggs during a single spawning season (Appeldoorn 2020). As noted above, the SRT determined that an estimated 5 million spawning adults remain in Saba and St. Lucia. Thus, the approximately 5 million queen conch at reproductively viable densities in this macroregion (see S5 in Horn *et al.* 2022) could produce up to 26 trillion eggs in a single spawning season. The jurisdictions within this macroregion also have reasonably high levels of self-recruitment (Figures 5, 6, and 8 in Vaz *et al.* 2022). Due to the high reproductive capacity of the estimated 5 million adult queen conch presently at viable densities within the Lesser Antilles macroregion and the high level of connectivity between jurisdictions that facilitate self-recruitment within the macroregion (Figure 6 a,c in Vaz *et al.* 2020), we determined that the Lesser Antilles macroregion is not currently at "high risk." Thus, we conclude that the Lesser Antilles portion of the species range is not currently in danger of extinction, but is likely to become so within the foreseeable future, due ongoing threats, and declining trends in abundance and productivity in the majority of the jurisdictions within the macroregion. This finding is consistent with the species' range wide determination, that queen conch is not currently in danger of extinction, but is likely to become so within the foreseeable future.

Based on our assessment of 39 management jurisdictions, 10 marine ecoregions, and one macroregion, we did not identify any portions of the species' range that were both "high risk" and "significant." Therefore, we conclude that there are no significant portions of the species' range that are currently in danger of extinction. Our conclusion regarding the species' overall extinction risk does not change based on consideration of status of the species within these portions of the species range, and thus we find that queen conch is not currently in danger, but is likely to become an endangered species within the foreseeable future throughout all of its range.

Conservation Efforts

There are several conservation efforts that have the potential to address the threats to the queen conch, including aquaculture and fisheries management and conservation plans. We considered ongoing queen conch aquaculture efforts being conducted by Florida Atlantic University's Harbor Branch Oceanographic Institute, Conservación ConCiencia, and Naguabo Fishing Association. These partners are working through a NOAA Saltonstall-Kennedy Grant Program funded project. The goal of the two year project (S-K NOAA Award NA10NMF4270029) is to assist with the restoration of queen conch fisheries in Puerto Rico by producing queen conch in a fishermen-operated aquaculture facility. With the declining conch populations in Puerto Rico and disruption of conch habitats from recent hurricanes, queen conch is a prime candidate for aquaculture. The facility will be open to fishermen, the local community, students and visitors to learn about queen conch aquaculture, biology, conservation, and fisheries. This project is anticipated to serve as a model that can be replicated in other fishing communities in Puerto Rico and elsewhere (Davis and Espinoza 2021).

In our discretion, we also considered foreign conservation efforts to protect and recover queen conch that are either underway, but not yet fully implemented, or are only planned, using these overarching criteria to determine whether these efforts are effective in ameliorating the threats we have identified to the species and thus potentially avert the need for listing. The 10-year Regional Queen Conch Fishery Management and Conservation Plan (Prada *et al.* 2017) was created following the recommendations of the first meeting of the WECAFC/CFMC/OPESCA/CRFM Working Group, held in Panama in 2012. The Regional Queen Conch Fishery Management and Conservation Plan was formulated with the following specific objectives: 1) improve the collection and integration of scientific data needed to determine the overall queen conch population status as the basis for the application of ecosystem-based management; 2) harmonize measures aimed at increasing the stability of the queen conch population and to implement best management practices for a sustainable fishery; 3) increase coordination and collaboration toward achieving better education and outreach, monitoring and research, co-management and strengthening, optimizing and harmonizing regional governance arrangements; and 4) adopt regional management measures, which incorporate the precautionary approach. While these conservation efforts are encouraging, it is difficult to assess the expected benefit to the species due to uncertainties surrounding their implementation. The management and conservation recommendation resulting from the Panama 2012 meeting are approximately 10 years old. Where recommendations were incorporated into fishery management strategies, we would have anticipated those benefits to be at least partially recognized, with improved data collection, updated population monitoring and assessments, or the implementation regulations that promote sustainable harvest. However, in most cases, we cannot ascertain whether new management measures have occurred, or if they have occurred, we cannot determine whether those benefits have been realized, given the information available at this time. In addition, the Organization of Eastern Caribbean States, in partnership with the United Nations Conference on Trade and Development (UNCTAD) and CITES, designed a pilot project in 2020 to test the application of the revised UNCTAD BioTrade Principles and Criteria in the marine environment, focusing on the queen conch value chain in Grenada, St. Lucia, and St. Vincent and the Grenadines (UNCTAD, 2021). This pilot project aims to empower small-scale fisheries to produce and trade queen conch products sustainably through the application of Blue BioTrade Principles and Criteria. The BioTrade Principles and Criteria, developed by UNCTAD, are a set of guidelines for businesses, governments, and civil society wishing to support the conservation and sustainable use of biodiversity, as well as the fair and equitable sharing of benefits through trade (UNCTAD, 2021). If successful, these efforts will likely improve some fisheries management and have the potential to decrease specific threats in the future. Nonetheless, we do not find that these conservation efforts have significantly altered the extinction risk for the queen conch to where it would not be at risk of extinction in the foreseeable future. However, we seek additional information on these and other conservation efforts (see **Public Comments Solicited** below).

Proposed Determination

Section 4(b)(1) of the ESA requires that NMFS make listing determinations based on the best scientific and commercial data available after conducting a review of the status of the species and taking into account those efforts, if any, being made by any state or foreign nation, or political subdivisions thereof, to protect and conserve the species. We have independently reviewed the best available scientific and commercial information, public comments submitted in response to the notice of a status review (84 FR 66685; December 6, 2019), the status review report (Horn *et al.* 2022), and other published and unpublished information, and we have consulted with species experts and individuals familiar with queen conch. We considered each of the statutory factors to determine whether it presented an extinction risk to the queen conch on its own, now or in the foreseeable future, and also considered the combination of those factors to determine whether they collectively contribute to the extinction risk of the species, currently or in the foreseeable future. Based on our consideration of the best available scientific and commercial information, as summarized here, including the SPR analysis, we conclude that while queen conch is not currently in danger of extinction throughout all or a significant portion of its range, it is likely to become so within the foreseeable future as a result of ESA section 4(a)(1) factors: B (overutilization for commercial, recreational, scientific, or educational purposes); D (inadequacy of existing regulatory mechanisms to address identified threats); and E (other natural or human factors affecting its continued existence). Accordingly, the queen conch meets the definition of a threatened species, and thus, we propose to list it as such throughout its range under the ESA.

Effects of Listing

Conservation measures provided for species listed as endangered or threatened under the ESA include recovery actions (16 U.S.C. 1533(f)), critical habitat designations (16 U.S.C. 1533(a)(3)(A)), Federal agency consultation requirements (16 U.S.C. 1536), and protective regulations (16 U.S.C. 1533(d)). Recognition of the species' status through listing also promotes conservation actions by Federal and state agencies, foreign entities, private groups, and individuals.

Identifying ESA Section 7 Consultation Requirements

Section 7(a)(4) of the ESA and NMFS/USFWS regulations require Federal agencies to confer with us on actions likely to jeopardize the continued existence of species proposed for listing, or likely to result in the destruction or adverse modification of proposed critical habitat. If a proposed species is ultimately listed, Federal agencies must consult under section 7 on any action they authorize, fund, or carry out if those actions may affect the listed species or designated critical habitat. Based on currently available information, we conclude that examples of Federal actions that may affect queen conch within the U.S. jurisdiction include, but are not limited to: fisheries management practices, discharge of pollution from point and non-point sources, contaminated waste and plastic disposal, development of water quality standards, and dredging.

Protective Regulations Under Section 4(d) of the ESA

We are proposing to list the queen conch as a threatened species. For threatened species, ESA section 4(d) leaves it to the Secretary's discretion whether, and to what extent, to extend the section 9(a) "take" prohibitions to the species, and also requires us to issue regulations the Secretary deems necessary and advisable for the conservation of the species. The 4(d) protective regulations may prohibit, with respect to threatened species, some or all of the acts which section 9(a) of the ESA prohibits with respect to endangered species. We are not proposing such regulations at this time, but may consider promulgating protective regulations pursuant to section 4(d) for the queen conch in a future rulemaking. In order to inform our consideration of appropriate protective regulations for the species, we seek information from the public on possible measures for their conservation.

Critical Habitat

Critical habitat cannot be designated within foreign nations. ESA implementing regulations at 50 CFR 424.12(g) specify that critical habitat shall not be designated within foreign countries or in other areas outside of U.S. jurisdiction.

Critical habitat is defined in section 3 of the ESA (16 U.S.C. 1532(5)) as: (1) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the ESA, on which are found (a) those physical or biological features essential to the conservation of the species and (b) that may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed upon a determination that such areas are essential for the conservation of the species. “Conservation” means the use of all methods and procedures needed to bring the species to the point at which listing under the ESA is no longer necessary. Section 4(a)(3)(a) of the ESA (16 U.S.C. 1533(a)(3)(A)) requires that, to the extent prudent and determinable, critical habitat be designated concurrently with the listing of a species. Designations of critical habitat must be based on the best scientific data available and must take into consideration the economic, national security, and other relevant impacts of specifying any particular area as critical habitat. To the maximum extent prudent and determinable, we will publish a proposed designation of critical habitat for the queen conch in a separate rule. We invite submissions of data and information on areas in U.S. jurisdiction that may meet the definition of critical habitat for the queen conch as well as potential impacts of designating any particular areas as critical habitat (see **Public Comments Solicited** below).

Policies on Peer Review

In December 2004, the Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review establishing minimum peer review standards, a transparent process for public disclosure of peer review planning, and opportunities for public participation. The OMB Bulletin, implemented under the Information Quality Act (Pub. L. 106-554) is intended to enhance the quality and credibility of the Federal government's scientific information, and applies to influential or highly influential scientific information disseminated on or after June 16, 2005. To satisfy our requirements under the OMB Bulletin, we received peer reviews from three independent peer reviewers on the status review report (Horn *et al.* 2022), which are available online (*https://www.noaa.gov/organization/information-technology/peer-review-plans*). All peer reviewer comments were addressed prior to dissemination of the final status review report and publication of this proposed rule. We conclude that these experts' reviews satisfy the requirements for "adequate [prior] peer review" contained in the Bulletin (sec. II.2.).

Public Comments Solicited

We intend that any final action resulting from this proposal will be as accurate as possible and informed by the best available scientific and commercial information. Therefore, we request comments or information from the public, other concerned governmental agencies, the scientific community, industry, or any other interested party regarding this proposed rule. In particular we seek comments containing: (1) new or updated information regarding queen conch landings and IUU fishing; (2) new or updated queen conch fisheries-dependent or -independent data including stock assessments; (3)

new or updated information on the status of the species, including surveys, density, and abundance information; (4) new or updated information regarding queen conch population structure, age structure, and connectivity; (5) new or updated information on queen conch range, habitat use, and distribution; (6) new or updated on data concerning any threats to the queen conch; (7) efforts being made to protect the species throughout its range; (8) new or updated queen conch fisheries management measures; or (9) other pertinent information regarding the species.

We are also soliciting information on physical and biological features that may support designation of critical habitat for queen conch within U.S. jurisdiction. Areas outside the occupied geographical area should also be identified if such areas themselves are essential to the conservation of the species. Physical and biological features essential to the conservation of the species may include, but are not limited to, features specific to individual species' ranges, habitats and life history characteristics within the following general categories of habitat features: (1) space for individual growth and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for reproduction and development of offspring; and (5) habitats that are protected from disturbance or are representative of the historical, geographical, and ecological distributions of the species.

References

A complete list of the references used in this proposed rule is available upon request, and also available at: *https://www.fisheries.noaa.gov/species/queen-conch*

Classification

National Environmental Policy Act

The 1982 amendments to the ESA in section 4(b)(1)(A), restrict the information that may be considered when assessing species for listing. Based on this limitation of criteria for a listing decision and the opinion in *Pacific Legal Foundation* v. *Andrus*, 675

F. 2d 825 (6th Cir. 1981), NMFS has concluded that ESA listing actions are not subject to the environmental assessment requirements of the NEPA (See NOAA Administrative Order 216-6A).

Executive Order 12866 and Regulatory Flexibility Act

As noted in the Conference Report on the 1982 amendments to the ESA, economic impacts cannot be considered when assessing the status of a species. Therefore, the economic analysis requirements of the Regulatory Flexibility Act are not applicable to the listing process. In addition, this proposed rule is exempt from review under Executive Order 12866.

Paperwork Reduction Act

This proposed rule does not contain a collection-of-information requirement for the purposes of the Paperwork Reduction Act.

Executive Order 13132, Federalism

In keeping with the intent of the Administration and Congress to provide continuing and meaningful dialogue on issues of mutual state and Federal interest, the proposed rule will be provided to the relevant agencies in each state or territory in which the subject species occurs, and these agencies are invited to comment.

List of Subjects in 50 CFR Part 223

Endangered and threatened species, Exports, Imports, Transportation.

Dated: August 30, 2022.

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Samuel D. Rauch III,

Deputy Assistant Administrator for Regulatory Programs,

National Marine Fisheries Service.

For the reasons set out in the preamble, we propose to amend 50 CFR part 223 as follows:

PART 223— THREATENED MARINE AND ANADROMOUS SPECIES

1. The authority citation for part 223 continues to read as follows:

Authority: 16 U.S.C. 1531-1543; subpart B, § 223.201-202 also issued under 16 U.S.C. 1361 *et seq*.; 16 U.S.C. 5503(d) for § 223.206(d)(9).

2. In § 223.102, in the table in paragraph (e), under the subheading "Molluscs," add an entry for "Conch, queen" in alphabetical order by common name to read as follows:

§ 223.102 Enumeration of endangered marine and anadromous species.

* * * * *

(e) * * *

Species[1]			Citation(s) for listing determination(s)	Critical habitat	ESA rules
Common name	Scientific name	Description of listed entity			
* * * * * * *					
Molluscs					
Conch, queen	*Aliger gigas*	Entire species	*[**FEDERAL REGISTER** citation and date when published as a final rule]*	NA	NA.
* * * * * * *					

[1] Species includes taxonomic species, subspecies, distinct population segments (DPSs) (for a policy statement, see 61 FR 4722, February 7, 1996), and evolutionarily significant units (ESUs) (for a policy statement, see 56 FR 58612, November 20, 1991).

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[FR Doc. 2022-19109 Filed: 9/7/2022 8:45 am; Publication Date: 9/8/2022]